AL 2 1985-340

MAY 14 1985

CANOLA PRODUCTION IN ALBERTA

Alberta
AGRICULTURE
FIELD CROPS BRANCH
AGDEX 149/20-1

ON 5432613

Copies of this publication may be obtained from:

Print Media Branch
Alberta Agriculture
7000 – 113 Street
Edmonton, Alberta, T6H 5T6
OR
Alberta Agriculture's district offices

1985 04 6M

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INTRODUCTION

The objective of this manual is to provide the grower with information that will help him maximize canola production for the greatest dollar return per unit area grown.

High canola production is dependent upon soil, climate, plant and management practices. Each crop production practice will affect crop growth within the system. While some crop production factors have a greater influence on yield than others, it is important that they all be in balance.

The information presented in this manual is a composite of the latest research and grower management practices. The manual covers basic crop production factors and their integration into a crop production system. The grower information was obtained in recent surveys of above-average canola growers situated in southern and central Alberta. The surveys covered the irrigated areas of southern Alberta and the Dark Brown, Thin Black, Black, and Grey-Wooded soil zones of central Alberta. The 392 growers completed an extensive questionnaire on how they managed crop production factors for canola production. Those growers who experienced abnormal rainfall, hail and disease damage, which could mask management factors, were eliminated from the data. Only those farms that received adequate rainfall throughout the growing season and did not report hail or moderate to heavy disease damage were selected. The data were sorted into two groups — a top yield group (average 40 bu/ac) and a low yield group (average 21 bu/ac). Growers in both the top and the low groups represented a good cross section of the total areas surveyed. A comparison of the management factors contributing to this 91 per cent average yield increase is contained in this manual. **The survey results are reported in bold face.** Research information came from many sources, but primarily from results obtained by Agriculture Canada and the universities in the prairie provinces.

AVERAGE CANOLA YIELDS

Average yields across Alberta vary due to differences in soil and climatic factors (Table 1). In each of the regions, there are individual growers who, with the same soil and climatic limitations as their neighbors, consistently achieve yields in the 30 to 40 bushels per acre range. The average yield of all the growers in the surveys was 30 bushels per acre. The grower surveys have shown that canola yields are not held down so much by soil and climatic limitations as they are by failure to apply, modify and adopt crop production factors into a balanced system. The growers who consistently obtain high yields pay careful attention to practices which will meet the crop's requirements for maximum growth at all its growth stages.

CANOLA VARIETIES

Canola varieties grown in Alberta belong to either the *Brassica napus* (Argentine types) or *Brassica campestris* (Polish type) species, which in turn belong to the much larger mustard family. Canola is closely related to the turnip, rutabaga, cabbage, cauliflower, kale, and brown and oriental mustard. Canola is more distantly related to many cruciferous weeds. These weeds in canola are therefore hard to control with herbicides.

Varieties are developed by plant breeders who make crosses among promising materials and carry out selection for yield and quality characteristics. After several years of selection, promising lines are entered into Canada's evaluation trials called Co-operative Tests which are located at over 20 locations across western Canada. Each line is evaluated for agronomic traits, quality and disease resistance. After three years of testing, only those lines which are better than existing varieties in some aspect, for example, higher quality, higher yield, triazine tolerance or better disease resistance, are licensed. It takes from eight to ten years from the initial crosses until a variety is licensed, followed by an additional two to three years of seed multiplication, before a new variety is in commercial production.

Table 1. Average Canola Yields by Area — 1978-83

Region	Census Division	Average Yield kg/ha	Average Yield bu/ac
ALBERTA			
Innisfail South	1-6	1,343	23.9
Innisfail North	7-14	1,225	21.8
Peace River	15	961	17.1
B.C./Peace River		961	17.1

The *B. napus* and *B. campestris* varieties have distinct agronomic characteristics which should be considered when selecting a variety to grow. The variety you select should meet the requirements of your own particular farming practices, timing of farming operations, and the area's frost-free period and growing season climate. The principal agronomic differences between the two species are outlined in Table 2.

Seed yields and agronomic characteristics vary not only between species but between varieties. Varieties may respond differently to rainfall, frost-free periods, and climatic conditions. The yield performance of the licensed canola varieties are shown in Table 3 for the different production areas. The *B. napus* variety, Westar, and the *B. campestris* variety, Tobin, were consistently the best in each species. The *B. campestris* varieties account for about 60 per cent of Alberta's canola acreage, with the *B. napus* varieties the remainder. The new triazine-tolerant variety, Triton, is significantly lower yielding, contains 3 per cent less oil and matures four days later than Westar. Triton is also more subject to lodging, and because of its lower seedling vigor, requires careful seedbed preparations. Triton should only be used where serious problems with cruciferous weeds such as wild mustard and stinkweed are expected.

Since varieties may change rapidly you are encouraged to consult the publication *Varieties of Cereal and Oilseed Crops for Alberta*, published each year by Alberta Agriculture. This will allow you to evaluate and select a variety suitable for your location and practices.

The surveys showed that the majority of the top group in southern Alberta grew *B. napus* varieties in southern Alberta, while in central Alberta, two-thirds of the top group grew *B. campestris* varieties.

GROWTH STAGES OF THE CANOLA PLANT

A grower who has an understanding of how a canola plant grows, and how its pattern of growth can be affected by what he does, can make more effective management decisions. The growth stages are shown in Figure 1. Following germination the seedling emerges about four to 10 days after seeding with a short stem and two cotyledons or seed leaves. Unlike barley, which keeps the growing point protected beneath the soil for five to six weeks, the growing point of canola is above the soil between the two cotyledons. The exposed growing tip makes canola seedlings more susceptible than cereal grains to spring frosts, soil drifting, insects and hail, or any other hazard which results in destruction of the seedling stem below the cotyledons. Four to eight days after emergence, the seedling develops its first two leaves. The leaves play a major role in canola plant growth. Rapid leaf development and growth allow the plant to collect more sunlight, encourage root growth, reduce soil moisture evaporation and will shade weeds. The larger the leaf area, the larger the plant will grow, and the greater its seed yield.

After forming from three to six leaves in the rosette stage, the plant "bolts" or rapidly sends up its stem with a cluster of flower buds at the top. Secondary branches also begin growing with flower bud clusters. The days from seeding to the end of the bud stages or first flower range from 30 to 50 days in *B. campestris*, and 40 to 60 days in *B. napus*, depending on the date of seeding and growing conditions. Rapid uniform emergence, and the development of a large leaf area which is maintained beyond the start of flowering, is important for high yields and can be promoted by proper seedbed preparation, timely planting and adequate moisture and nutrients.

Flowering begins with the opening of the lowest bud on the main stem and continues upward with three to five or more flowers opening per day. Full plant height is reached at peak flowering. Under reasonable growing conditions, flowering of the main stem will continue from 14 to 21 days for both species. Canola plants produce more buds and flowers than

Table 2. Agronomic Characteristics of *B. napus* and *B. campestris*

Characteristic	*Brassica napus*	*Brassica campestris*
Seed yield	Yields high under good moisture and frost-free conditions	Under good growing conditions, 15 to 20% less than *B. napus*; under frost or drought about equal to *B. napus*
Days to mature	Same as wheat	10 days to 3 weeks earlier than wheat
Height	Depends on growing conditions; ranges from 75 to 175 cm (30-69 in.)	Depends on growing conditions; ranges from 50 to 125 cm (20-49 in.)
Lodging	Varies with variety	Varies with variety
Disease tolerance	Varieties similar but more resistant than *B. campestris*	Very susceptible to disease; Tobin has white rust resistance, while Candle is susceptible.
Frost damage	Slightly more susceptible to late spring frosts than cereals; susceptible to early fall frosts	More resistant to late spring frosts and usually mature before fall frosts
Drought tolerance	Similar to cereals; may suffer loss in yield and quality from late summer drought	Similar to cereals; often mature early enough to escape late summer drought
Shattering	Shatters readily when ripe	More resistant to shattering; may be straight combined
Flowering	May flower during high temperature periods in July with reduced pod set	Usually finishes flowering before higher temperature occur

Table 3. Recommended Varieties of Canola for Alberta — 1985

Variety	Yield as % of Candle in Areas: Irr. 1&2	1	2	3	4	5	6	Relative Maturity	Straw Length	Remarks
POLISH TYPE (*B. campestris*)										
Candle*	100	100	100	100	100	100	100	Early	Medium	Mixed yellow and brown seed
Tobin	115	120	115	100	105	105	95	Early	Medium	Mixed yellow and brown seed
ARGENTINE TYPE (*B. napus*)										
Altex*	125	110	120	120	105	125	110	Med-late	Long	
Andor*	115	110	120	120	105	130	105	Med-late	Long	
Triton	90	XX	100	90	85	100	85	Late	Long	Triazine resistant, lower oil content
Westar	125	105	130	125	110	140	125	Med-late	Long	

REMARKS: Polish type — 2-3 weeks earlier than Argentine type. Argentine type shatters more readily than Polish when ripe, and requires early seeding in Areas 4, 5 and 6. Argentine canola is very risky in Areas 5 and 6 because of later maturity. Mixtures of canola and mustard are inseparable and unacceptable. All canola cultivars are low in erucic acid and glucosinolates.
XX — No data available.

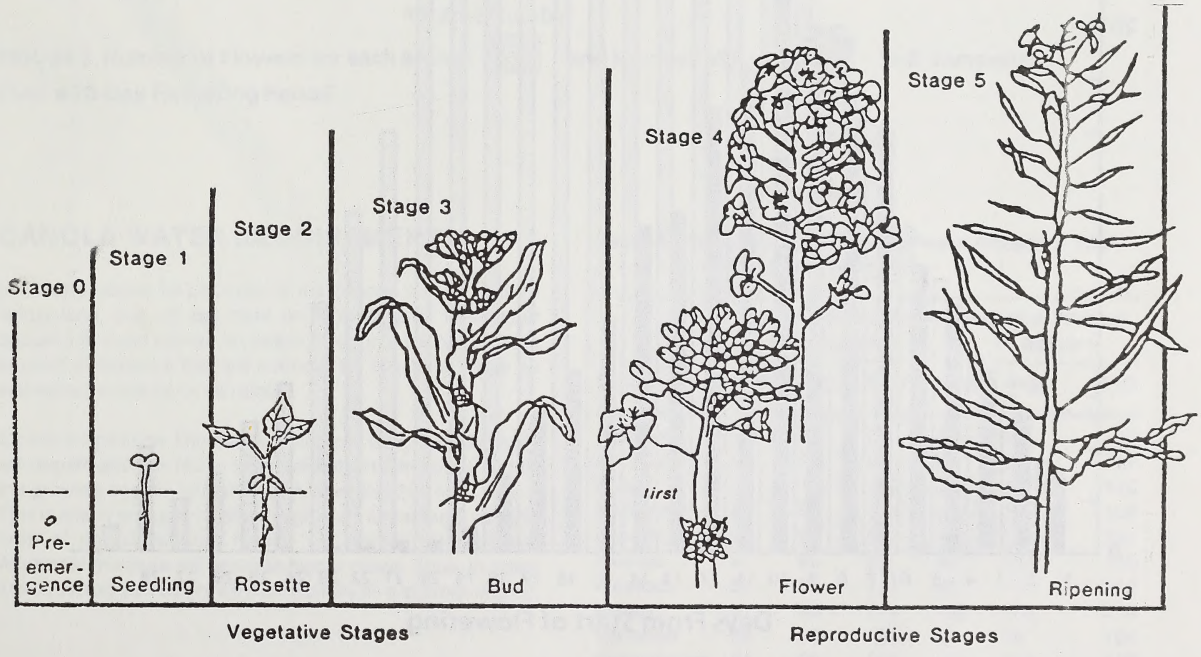


Figure 1. Growth Stages in *B. campestris* and *B. napus*.

can develop into productive pods. Normally, only 40 to 55 per cent of the flowers produced on a plant develop productive pods that are retained until harvest (Figure 2). Most of the productive pods are from flowers which opened within 15 days of flowering on the main stem and first few secondary branches (Figure 3). Later flowers and pods usually abort. Lack of nutrients or water, weed competition, and insect and disease damage affect the numbers of productive pods formed at this stage.

Ripening begins with petal drop from the last formed flower on the main stem. Flowering on the later secondary branches may continue for some time; however, these do not usually produce productive pods. Seeds develop in the pods, and 35 to 45 days after flower opening, seed filling is complete. When physiologically mature, the seeds contain about 40 per cent moisture, the seed coat begins changing color, and seed moisture is rapidly lost at 2 to 3 per cent per day. The seeds in the first formed pods lower on the plant ripen first at 40 to 60 days after first flower. The plant is ready to swath when 30 to 40 per cent of the seeds on a plant have a color change, the seed in the last formed pods at the top are nearing physiological maturity, and the average seed moisture is about 30 to 35 per cent. *B. campestris* varieties can mature anywhere from 69 to 111 days from seeding, while *B. napus* varieties require from 88 to 133 days (Table 4). Days to mature depend on location, growing season and date of seeding. Some of the growth stage characteristics of the two species are shown in Table 5.

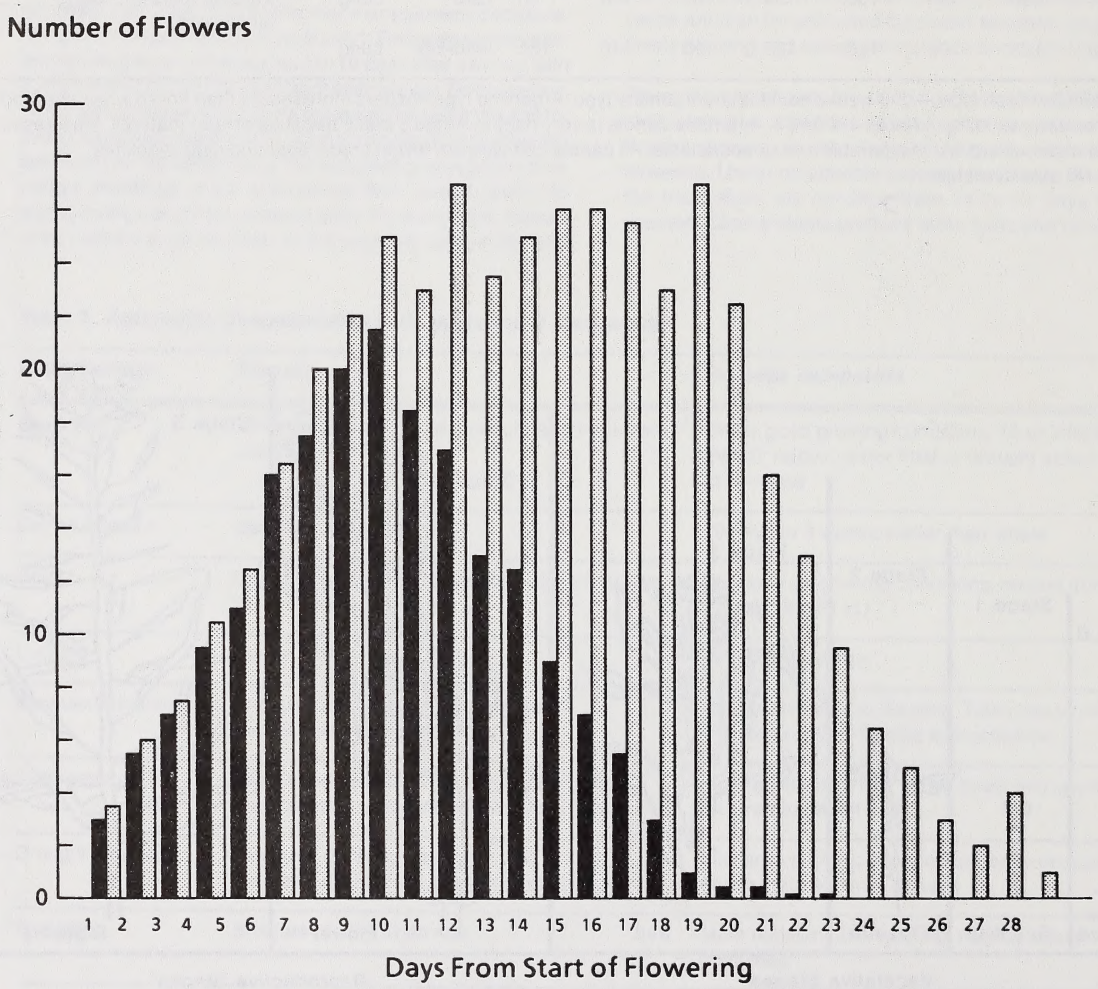


FIGURE 2 Total Number of Flowers Opened Per Day Over the Whole Plant and the Number of Flowers Which Formed Pods Retained to Maturity in *B. napus* Plants

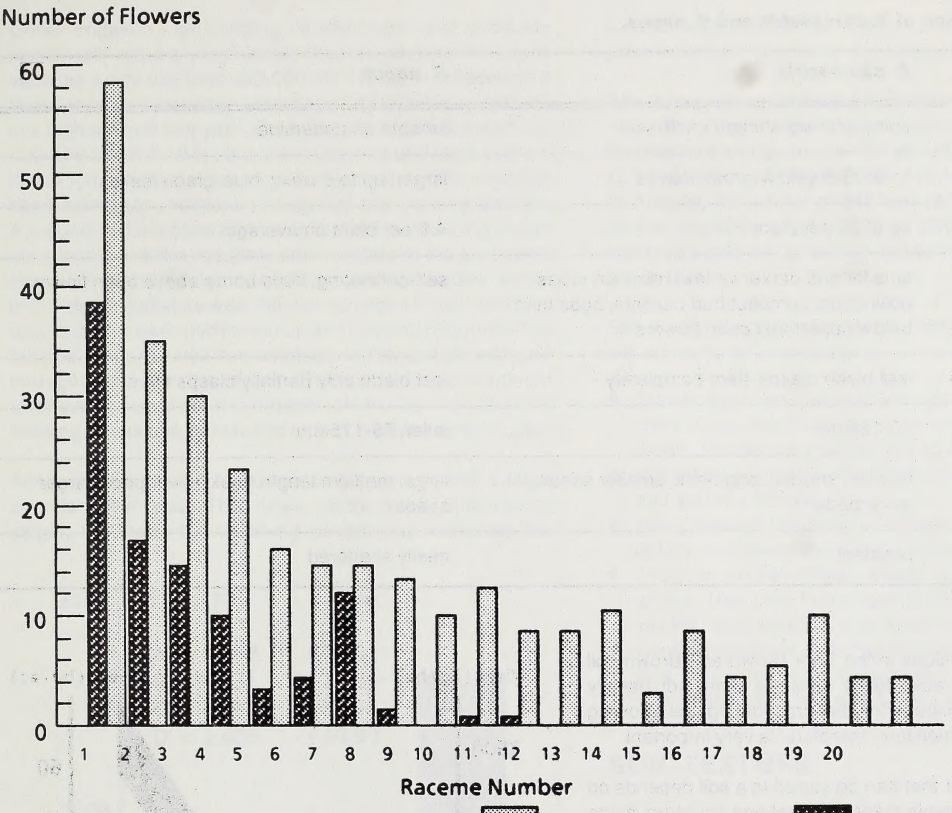


FIGURE 3. Number of Flowers for each Branch and Number of Pods in *B. campestris* Over a 20-Day Flowering Period

CANOLA WATER REQUIREMENTS

In Alberta, about 60 per cent of the canola is produced on fallow land, and 40 per cent on stubble land. Base your decision to seed canola on fallow or on stubble land on the amount of moisture that will normally be available, either as soil-stored moisture or as rainfall.

Canola crops in the Thin Black, Black and Grey-Wooded soils will require 350 mm (13 to 14 in.) of water. In these soil zones, the growing season rainfall usually exceeds 260 mm (10 in.). This is nearly enough moisture to grow an acceptable yielding crop of canola without relying on stored soil moisture. Additional moisture will result in higher yields. Thus, in these areas, canola can be grown successfully as a stubble-in crop.

Table 4. Range in Maturity at Different Research Trial Locations and Years

	Range in Days From Seeding to Harvest					
	B. campestris			*B. napus*		
Location	**Low**	**Avg.**	**High**	**Low**	**Avg.**	**High**
Lethbridge	69	72	81	88	89	90
Irricanna	86	89	90	96	99	102
Olds	98	104	110	107	113	120
Penhold	95	98	104	102	105	108
Lacombe	91	97	108	102	118	127
Ellerslie	91	95	99	101	107	113
Westlock	89	91	107	98	105	112
Kelsey	81	98	111	100	106	114
Vermilion	89	93	109	95	98	104
Beaverlodge	84	96	108	103	119	133
Fort Vermilion	88	94	100	106	116	130

Table 5. Comparison of *B. campestris* and *B. napus*.

Characteristic	*B. campestris*	*B. napus*
Cotyledons	spiny and wrinkled on underside	smooth on underside
Rosettes	small, 3-5 yellow-green leaves	larger, up to 6 waxy, blue-green leaves
Branches	up to 20 per plant	4-6 per plant on average
Flowers	smaller and darker yellow; relies on cross-pollination; compact bud clusters; buds held below uppermost open flowers	self-pollinating; buds borne above open flowers
Leaves	leaf blade clasps stem completely	leaf blade only partially clasps stem
Height	50-125 cm	taller, 75-175 cm
Pods	smaller, shorter, long beak, smaller seeds, more pods	large, medium length beak, fewer pods, larger seeds
Shattering	resistant	easily shattered

Under dryland conditions in the Dark Brown and Brown soil zones, rainfall plus soil stored moisture does not usually provide enough moisture for the crop during the growing season. Stored soil moisture, therefore, is very important.

The amount of water that can be stored in a soil depends on the soil's texture, organic matter content and structure. It can be calculated roughly by measuring the depth to which the soil is moist. Moist soil will form a ball when it is squeezed in the hand. The amount of plant available water stored in equal depths of various textural classes of soil is shown in Table 6.

Table 6. Stored Soil Moisture.

Soil Texture	Approximate Depth of Plant Available Water in Moist Soil	
	cm/30 cm soil	in/ft soil
Heavy (Clays and Silty Clays)	5.0	2.0
Medium (Clay Loams, Silt Loams, Loams)	3.75	1.5
Coarse (Sandy Loams and Sands)	2.5	1.0

If you know the amount of stored soil moisture reserves and expected average growing season rainfall, you can decide whether to seed canola on stubble land or fallow.

Generally, 25 mm (1 in.) of water will result in about 2.75 bushels per acre of yield under good growing conditions and adequate fertility (Figure 4).

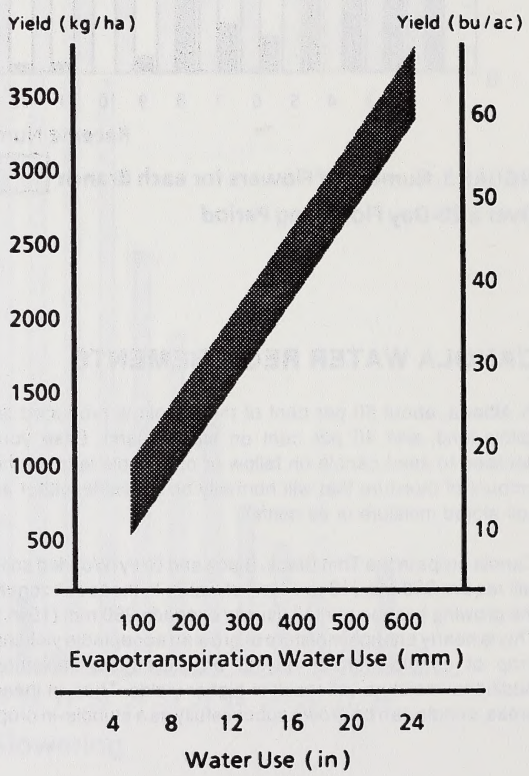


Figure 4. Moisture use and canola yield.

Under irrigation high yielding canola crops with adequate fertility will require more water than on dryland. *B. napus* varieties would use from 450-550 mm (18-22 in.) of water in a lower water use growing season, and 600-700 mm (24-28 in.) in a higher water use year. *B. campestris* varieties would use 400-450 mm (16-18 in.) in a lower use year and up to 600 mm (24 in.) in a higher use year. Canola plants under irrigation need adequate moisture throughout the growing season. Adequate soil moisture can be defined as maintaining 50 per cent or more of the available soil moisture in the root zone. Research at Lethbridge has shown yield responses where available soil moisture was maintained above 50 per cent only up to budding, early pod formation and ripening (Figure 5). The greatest yields resulted from adequate fertility and soil moisture throughout the growing season. The exact timing and amount of irrigation required will depend on the soil moisture at seeding, rate of use, rainfall and type of irrigation system used.

Adequate soil moisture promotes root growth and a large abundant leaf area. This helps plants retain their leaves longer, lengthens the flowering period, and increases the number of branches per plant, number of flowers forming pods, seeds per pod, seed weight and seed yield.

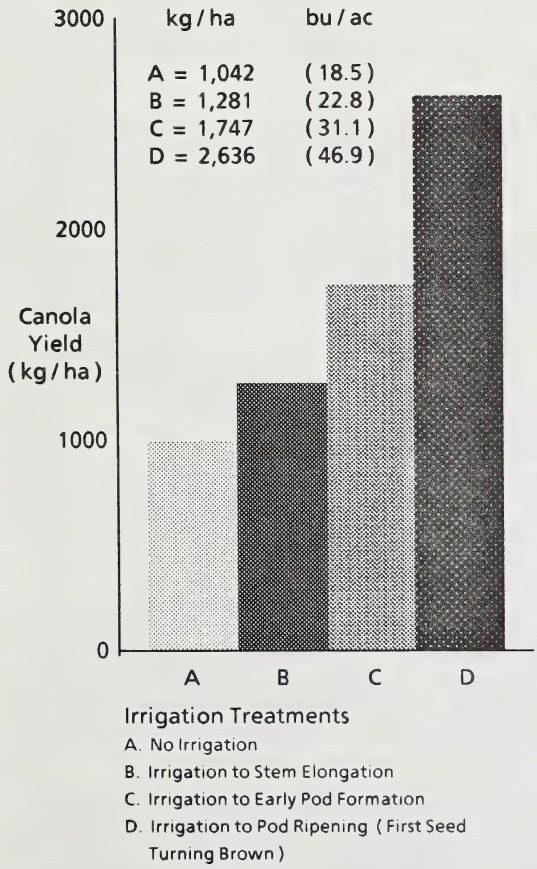


Figure 5. Yields of canola under four levels of irrigation.

The survey showed that the distribution and amounts of rainfall during the growing season were similar for both the top and low groups — 30 mm (1.2 in.) in May, 70 mm (2.8 in.) in June, 118 mm (4.7 in.) in July, and 25 mm (1 in.) in August, for a total of 243 mm (9.7 in.). The top group under irrigation applied 225 to 250 mm (9 to 10 in.) of water in addition to rainfall, while the low group applied much less.

Soil water management strategies that can increase available soil moisture for crop use are:

- Conserving snow moisture through crop residue management. Crop residue traps snow and reduces snowmelt runoff, thereby increasing spring stored water.
- Increasing soil organic matter which improves soil structure and water infiltration.
- Using fertilizers to maintain crop yields on stubble. Adequate fertility increases the crop's water use efficiency.
- Avoiding excess tillage which increases soil moisture losses. Use only those operations necessary for weed control, land leveling and seedbed preparation.
- Controlling weeds, insects and diseases. Weeds use water at a similar rate to canola plants. Insects and diseases reduce the plant's ability to use water.

SOIL TEXTURE

Medium textured soils such as loams, clay-loams and silty-clay loams are most suitable for canola production because they allow moisture infiltration, and have good water holding capacity and adequate drainage. These soils have a granular structure that allows them to be firmly packed for a seedbed without baking and crusting. Most agricultural soils in Alberta fall within these textural classes.

If well managed, fine textured soils can produce good canola crops. In drier areas, clay soils, with their higher water holding capacity, are better able to carry canola crops through short periods of drought. However, clay soils are more prone to becoming water logged than sandy loam or loam soils. Also, clay soils tend to remain wet and cold in the spring which often results in slow germination and uneven growth providing little competition to early weed infestations. Fine textured soils, low in organic matter, often have poor structure and crust easily, thereby reducing seedling emergence.

Unless irrigated, sandy soils are usually not suitable for canola mainly because of their low moisture-holding capacity. These soils cannot store sufficient moisture to support a canola crop through periods of drought.

Soil texture was not a major factor in the survey as the majority of the top and low groups were on loam to clay loam soils. A much higher percentage of the top growers were aware of what their soil textures were.

CANOLA TEMPERATURE AND FROST-FREE PERIOD REQUIREMENTS

If you know the growing-degree-days and frost-free period for your location you can select the best suited variety with the least amount of risk. Growing-degree-days measure the accumulated heat above a base temperature of 5°C. Very little significant plant growth occurs at temperatures below 5°C. Growing-degree-days are calculated by adding together the daily mean temperatures above the base temperature of 5°C. If, the day after the crop is sown, the mean temperature is 16°C the crop has received 16 - 5 = 11 growing-degree-days. Only those growing-degree-days after the crop is sown are included. *B. napus* varieties have a heat requirement similar to wheat, which needs 1040 to 1100 growing-degree-days, while *B. campestris* varieties have similar heat requirements to barley, which needs 860 to 920 growing-degree days. If you grow *B. napus* varieties in areas that have fewer growing-degree-days than the crop requires, late maturity results and there is a risk of fall frost damage. Days to mature should match the location's heat accumulation and frost-free period. The average length of frost-free period in parts of the Peace River region, and much of the southern third of Alberta, ranges from 100 to 120 days (Figure 6). Under good management there should be no difficulty in maturing the recommended varieties for Alberta in those areas.

At higher elevations, along the western boundary of the province, and in other areas of the Peace River region and parts of north and west central Alberta, the frost-free period is often too short to properly mature *B. napus* varieties and the risk of fall frost damage is high.

FROST DAMAGE

Canola seedlings will usually recover from a light spring frost. If a heavy frost does blacken the leaves, no action should be taken for at least four to ten days until regrowth is noticeable. Even if two-thirds of the seedlings are killed, the field will usually produce more when left than if reseeded. The surviving plants will take advantage of the reduced competition and grow larger, producing more branches, pods and seeds per pod, thereby compensating for lost plants. These plants may mature five to eight days later than a crop with no damage, but a reseeded crop would mature even later. Spring frost damage to canola seedlings has been only a minor problem.

The amount of fall frost damage to canola depends on its stage of maturity. Three degrees of frost is enough to kill immature seeds containing 50 to 60 per cent moisture, while those ready to swath at about 35 per cent moisture will normally escape damage.

HAIL DAMAGE

Canola plants at the seedling stage must be greatly reduced in number before yield losses occur. The plants have a remarkable ability to recover from hail damage. Hail damage occurring from the seedling to early bud stage will cause a seed yield loss equal to about 25 per cent of the leaf area loss. When buds and flowers are lost at an early flowering stage, the plants may recover rapidly by development of flowers from buds not damaged and by producing new flowering branches lower on the plant. These replace, to a degree, the damaged buds, flowers and pods. Seed yield will depend on the percentage of leaves and branches lost. If hail strikes during pod filling or ripening, plant recovery is not possible. Even if the plants do rebranch and flower, there is insufficient growing season left to allow this new growth to reach maturity before a frost.

CANOLA RESPONSE TO ACIDITY, SALINITY AND SOLONETZIC SOIL

Acidity, salinity and solonetzic soil problems may be major limiting factors in canola production, if they exist at levels that reduce growth and yield. When these problems are severe, they are very visible and easily determined. At less limiting levels, they may not be as recognizable but still reduce growth and yield.

Soils are either acid (sour), neutral or alkaline. Soil acidity can be determined by a soil test and is expressed as a pH value. A pH value of 7.0 is neutral, meaning the soil is neither acid nor alkaline. In practical terms, a soil below pH of 6.5 is called "acid" and above 7.5 is "alkaline." On very strongly acid soils with a pH of less than 5.5, canola yields are often substantially reduced. Research has shown that yields of canola on such soils can be substantially increased by lime application.

All soils contain soluble salts (those which dissolve in water). Those containing amounts sufficient to be harmful to plants are called "saline" soils. The term "alkali" is often incorrectly used to refer to saline soils. Soils with a pH greater than 7.5 are called alkaline. A soil with a high degree of alkalinity (pH of 8.5 or higher) is called an alkali soil. Canola will tolerate soils with a pH of up to 8.3 before yield reductions are serious. Most saline soils are neutral to slightly alkaline (below pH 8.5). A soil test can determine the extent of salinity. The degree of salinity or total soluble salt concentration is measured with a conductivity test. If the soil analysis rates the soil at 0-2 conductivity, the soil is slightly saline; at 5-10 conductivity, the soil is moderately saline; at 11-16, very saline; and over 16, extremely saline. Canola is considered moderately tolerant and can tolerate salinity up to levels of 5-6 conductivity; however, reductions in yield can be expected at level 4 conductivity (Figure 7).

Solonetzic soils, often called burn-out, blow out, or gumbo soils are characterized by a tough, impermeable, high sodium, clay hardpan from 2 to 12 in. or more below the surface. This hardpan layer severely restricts root and water penetration below the topsoil. The deeper the depth of topsoil, the greater the moisture storage available and the more likely the success of growing a canola crop. Seedbed preparation is relatively

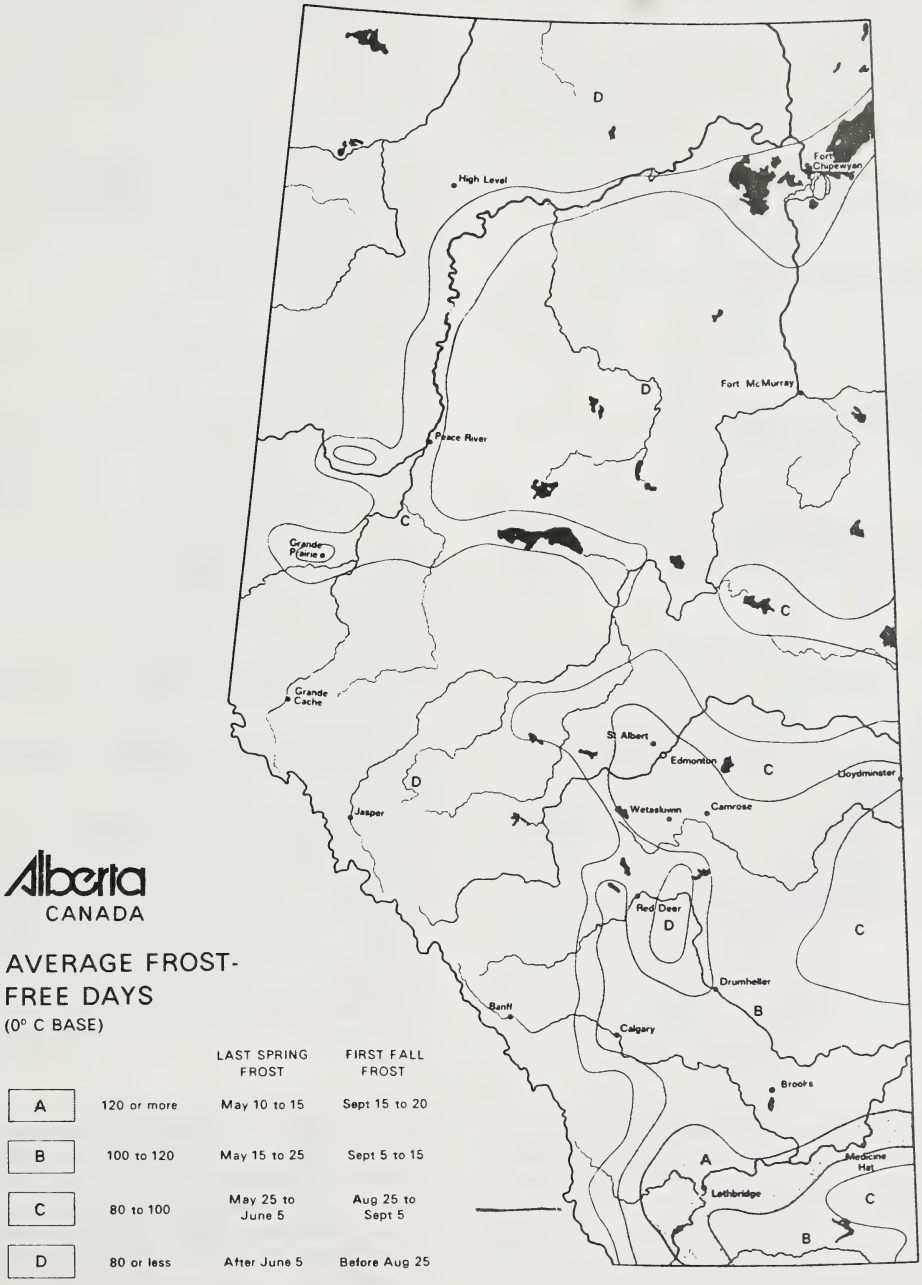


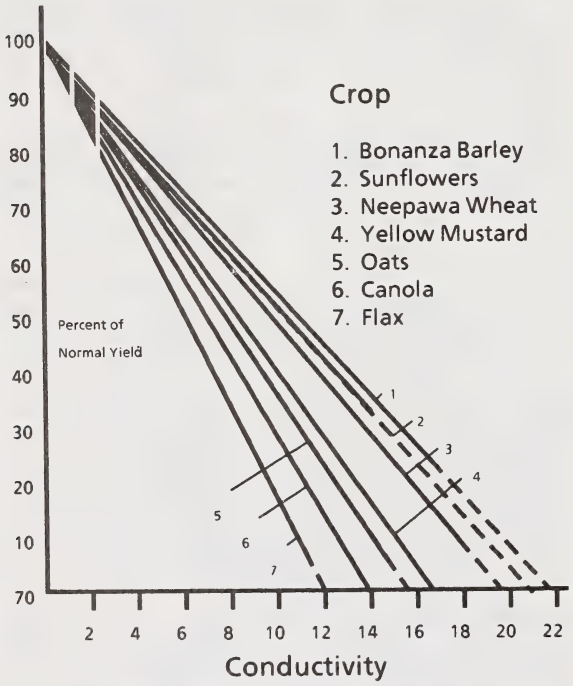
Figure 6. Map showing average number of frost free days in Alberta.

difficult on solonetzic soils with shallow topsoil as they dry out rapidly with cultivation. If tilled when wet, solonetzic soils form large, hard clods, which are difficult to break down into a good seedbed, resulting in poor and uneven germination. In addition, the surface soil structure tends to break down easily under rainfall and dries to form a hard crust which restricts seedling emergence. Solonetzic soils are usually in patches in a field with good soil. Abundant growth on the good soil is often contrasted by thin stunted growth on the solonetzic patches. Deep plowing and deep subsoiling (ripping) have increased production on some solonetzic soils.

Where acidity, salinity and solonetzic soil problems occur, you should consult with your district agriculturist and provincial soil specialists to devise methods to combat these problems.

SOIL PREPARATION FOR CANOLA PRODUCTION

Few field operations are more closely related to success or failure in canola production than is seedbed preparation. Canola seedlings do not develop as quickly as cereals do to provide competition against weeds. The best defence against broadleaved weed competition is to obtain rapid germination, emergence and growth of the crop. Uniform shallow seeding to moisture promotes rapid emergence and enables the crop to compete with weeds. Anything that adversely affects seed germination and emergence can cause significant reduction in plant populations, seedling vigor and, subsequently, yield.



The steeper the slope line, the less tolerant the crop.
Note: The solid portions of slope lines are known values.
The dotted portions are projected values.

Figure 7. Yield response of seven crops to various salinity levels.

For canola, the seedbed should be reasonably level, uniform, well packed, and moist throughout its depth. If possible, the soil surface should have a good granular structure with 30 to 45 per cent fine material (granules up to 1/25 in. in size), and the rest ranging up to 1/5 in. in size, with only enough larger lumps to prevent wind erosion.

CANOLA PRODUCTION ON FALLOW LAND

Good fallow land intended for canola production the following year can be prepared and maintained with a wide range of tillage implements operated alone or in conjunction with broad-spectrum herbicides. Since tillage reduces crop residue cover and soil moisture, you may wish to control weeds with fall or spring-applied herbicides, thereby maintaining crop residues for erosion protection. Tillage should be from 9 to 10 cm (3-4 in.) deep, consistent with good weed control. Blade cultivators and heavy-duty cultivators perform the most satisfactorily. These cultivators cut off roots below the surface and loosen surface soil, leaving most of the trash on the surface. The blade cultivator is the best implement for drier soils where wind erosion is a problem, but may not work well in moist black soils high in organic matter. The heavy-duty cultivator, combined with rod weeder, gives better weed control, levels the field and leaves more residue on the surface. Disc-type tillage implements reduce the crop residue cover by about 50 per cent with each operation.

In the fall of the fallow year, take soil samples to determine the fertilizer requirements of the canola crop. You may use soil incorporated granular herbicides in the fall. This spreads the spring workload, reduces the drying of the seedbed in the spring, and helps maintain some crop residue on the surface. In early August, discontinue tillage and use herbicides for controlling broadleaved and winter annual weeds. Kill cereal growth that becomes too high with a tillage operation that leaves the soil rough or cloddy with residues on the surface.

FALLOW SEEDBED PREPARATION

Minimum tillage before seeding usually resulted in the highest yields where weed control was satisfactory and seeding done before the soil dried. Where tillage is necessary on fallow, the most popular operation is with a vibra shank with mounted harrows run at a shallow 5 to 8 cm (2 to 3 in.) in depth. Deeper tillage may help in weed control but dries out the seedbed. Further tillage, if necessary, should not be deeper than the first cultivation. When herbicides are spring incorporated, pay particular attention to firming the soil with packer-harrow drawbars or rod weeders. It is essential to preserve moisture at a shallow depth for rapid germination and emergence, so that canola seedlings can provide adequate competition to later germinating weeds. Spring tillage, followed by a delay to

allow one or more crops of weeds to be killed, can result in cleaner crops, but, under dry spring conditions, the surfaces may become too dry for canola germination. Delayed seeding may also result in lower yields and increase the risk of fall frost and damp harvest weather.

FALL STUBBLE TILLAGE

To help achieve the desired seedbed for canola in the spring, distribute the trash uniformly over the soil surface in the fall. Swathing as high as possible and leaving a stubble that still supports the swath will aid this distribution. The taller standing stubble will catch snow and protect the soil against wind and water erosion, particularly in drier areas. In higher rainfall areas, and on irrigated land where heavy crop residues may hinder spring seedbed preparation, or on soils prone to staying wet and cold in the spring, leave shorter stubble that will hold less snow as an aid to drying fields in the spring. Unless the straw is to be baled or removed for feed or bedding, equip combines with efficient straw choppers and deflectors that uniformly distribute crop residues. Further distribute the crop residue by harrowing with tine harrows at an angle to the combine rows on a dry day. Crazy (oscillating) harrows work best in spreading trash evenly over the soil surface.

Never burn crop stubble. Burning reduces soil organic matter, damages soil structure and reduces plant nutrient availability. Initially, yields of canola grown on burned stubble land may increase slightly, but repeated burning reduces yields.

Before freeze-up, take appropriate soil samples to determine fertilizer requirements.

Fall tillage helps reduce excessively heavy crop residues and facilitates seedbed preparation in the spring. It is preferable to fall cultivate with a heavy duty cultivator or field cultivator which leaves some stubble to trap snow and to allow more rapid penetration of snow melt moisture. This is more important in clay and clay loams than in loam or sandy loams. Shallow cultivation, done shortly after harvest, covers weed seeds and scattered grain and promotes fall germination of such seeds. Deep cultivation tends to bury weed seeds and aggravates the problem posed by dormancy in wild oats and other weeds which germinate later, when subsequent tillage lifts them near the soil surface. Excessively deep cultivation also allows for loss of critical soil moisture in areas of limited precipitation.

If crop residue is lodged and/or heavy, use a double disc or discer. To prevent erosion, the soil should not be worked too finely, and one half of the crop residue should be maintained on the surface. Nitrogen fertilizer can be banded with air flow applicators 10 to 15 cm (4 to 6 in.) deep or shanked or knifed in as anhydrous ammonia when soil temperatures at 10 cm (4 in.) are less than 10°C. Granular herbicides applied after an initial stubble tillage at 7 to 10 cm (3 to 4 in.) should be incorporated with a tandem disc, discer or field cultivator. The second incorporation should be at right angles to the first incorporation. If the first incorporation reduces crop residue cover so that a second incorporation would leave the soil open to erosion, the second incorporation should be left until spring.

The grower survey indicated that the top growers do much of their preseeding work in the fall. The top group commonly used two tillage operations with heavy duty cultivators with spikes or shovels and mounted harrows to incorporate heavy residues. In the top group 60 per cent applied nitrogen and 30 per cent applied herbicides in the fall, whereas growers in the low yield group applied 40 per cent and 5 per cent respectively. Possible reasons for this are:

1. **Time saved facilitates earlier spring seeding.**
2. **Fewer soil drying operations are needed in the spring.**
3. **Fertilizers and herbicides costs are often lower in the fall than in the spring.**

These advantages must be balanced against:

1. **Possible loss of product (fertilizer and herbicide) over the winter.**
2. **Potential for soil erosion.**
3. **The grower's cash flow situation in the fall.**
4. **The inability to adjust planting intentions when market conditions change.**

STUBBLE SEEDBED PREPARATION

Minimum shallow spring tillage usually results in higher yields. Tillage should normally begin as soon as weed and volunteer growth occurs. In west-central and northern Alberta some growers till the land as early as soil moisture will allow, to try and warm the soil and stimulate weed seed germination. On fine textured soils, a shallow 1 in. cultivation early in the spring will create a soil mulch which interrupts upward capillary movement of water, thereby reducing evaporation. This will help maintain soil moisture near the surface for germination with a later seedbed preparation and planting.

Early spring tillage for the incorporation of herbicides and fertilizers and reduction of trash can facilitate the preparation of a better seedbed. Any tillage operation results in rapid moisture loss to the depth of tillage. Packing reduces moisture loss but may result in ineffective weed control. Early application and incorporation when the weather is cooler will reduce moisture loss, especially where a prolonged dry spell occurs after seeding. If seedbed moisture is a problem, a fall application and incorporation of fertilizers and herbicides may be preferable where erosion is not a problem.

Initial tillage should be shallow, 5 to 7 cm (2 to 3 in.), deep enough to kill weeds yet still conserve soil moisture. A field cultivator (vibra shank) with harrows or disc-type field implement, followed by a rod weeder or harrows, is usually satisfactory where crop residue is light. For land with a heavy residue cover, the heavy duty cultivator with sweeps or blades plus harrows, or the tandem disc with harrows, are the most popular. Subsequent tillage operations, if required, should not be deeper than the first. Excessive tillage will pulverize the soil surface and dry out the seedbed. Where more than one tillage operation is required, the final spring tillage, just before seeding, should be done with a vibra shank or similar type cultivator, operated shallowly and followed by harrows, packers

or rod weeders to firm the loosened soil. Seedbeds must be firm to reduce drying and to aid in planter depth control. If the seedbed is dry, extra packing may help bring moisture up.

MINIMUM OR NO-TILL CANOLA PRODUCTION

Canola is normally grown under conventional tillage practices, however, many growers and researchers have grown canola under reduced tillage systems with varying degrees of success. Reduced tillage systems require more management with particular attention paid to trash distribution, weed control, fertilizer application and seed placement. Research trials show that reasonable yields can be obtained from canola under no-till systems (Table 7).

Table 7. Canola Yields Under No-Till and Conventional Tillage

	No-Till Bu/ac	Conventional Till Bu/ac
Canola on wheat stubble, 1980	19.9	19.4
Canola on fallow, 1980	23.0	17.4
Canola on fallow, 1981	25.0	25.8

Weeds can become a problem in canola on no-till because there are no herbicides licensed for post-emergence control of broadleaved annuals. Because soils under no-till are often cooler and wetter than tilled soils, no-till production may not be suitable in some central and northern parts of Alberta where the growing season is short. Heavy trash, especially on clay soils, may keep the soil too wet to be seeded at the optimum time for high yields. Canola crops under no-till are usually later in maturity as well. Heavy crop residues in these areas make proper seed placement through heavy trash difficult with most seed drills.

Researchers and many growers have found that conventional tillage can be reduced and still obtain reasonable yields (Table 8).

Results from the surveys clearly showed that top growers paid close attention to their spring tillage and seedbed preparation. In the year the surveys were conducted, 42 per cent of the canola grown in Alberta was on stubble, with yields 18 per cent lower than average summerfallow yields. In the surveys 72 per cent of the growers stubble cropped canola with yields only 3 per cent less than those who grew canola on summerfallow. The majority of top growers:

1. **Achieved a firm to very firm seedbed 70 per cent vs 31 per cent in the low group.**
2. **Used more rod weeders, packers and harrows.**
3. **Used more attachments like harrows on their tillage equipment.**
4. **Used fewer, shallower tillage operations prior to seeding.**
5. **Had moisture within 1 in. of the soil surface.**
6. **Incorporated a herbicide in the fall or spring.**
7. **When asked to rate their seedbed, 85 per cent of the top yield group felt they had achieved a very good to excellent seedbed, compared with only 65 per cent of the low group.**

In the top group, 75 per cent used conventional tillage and 25 per cent used minimal tillage, while in the low group, 95 per cent used conventional tillage.

Table 8. Effect of Conventional and Reduced Tillage on Canola Yields

	Field Operations						
	1	2	3	4	5	6	7
Fall 1979	Harrowed 8 oz - 2,4-D	Tillage	Tillage	8 oz - 2,4-D	8 oz - 2,4-D	8 oz - 2,4-D	8 oz - 2,4-D
Spring 1980	Harrowed, tilled & oscillating harrowed	Treflan, 3 tills & harrowed	Treflan, 3 tills & harrowed	Harrowed, Roundup & Torch	Harrowed, Roundup & Torch	Harrowed, Roundup & Torch	Harrowed, Roundup & Torch
May 12	Air seeder	Double press	Hoe press drill	Hoe press drill	Triple disc drill	Air seeder	Discer & packer
June 10	Hoegrass	Hoegrass	Hoegrass	Hoegrass	Hoegrass	Hoegrass	Hoegrass
Sept 5 swathed no. plants/m	58	95	46	28	25	38	45
Dockage*	6.4	0.5	0.5	1.2	1.8	4.6	3.6
Net yield kg/ha	1926	2035	1984	1940	1806	1764	1782
bu/ac	34.3	36.2	35.3	34.5	32.1	31.4	31.7

**Dockage was mainly due to volunteer wheat.*

FIELD SELECTION FOR CANOLA

Carefully select a field for canola to avoid a buildup of disease, insects, or hard-to-control weeds. Do not grow canola on the same field for at least three years after a previous canola crop. Also consider volunteer growth from previous crops which may cause serious competition and seed separation problems. Chemical residues from herbicides safe for other crops may also carry over in the soil and adversely affect canola. No one particular crop rotation will suit all circumstances. The information in Table 9 is a guide for selecting a field for canola.

Growers in the survey who seeded their canola on a summerfallow or stubble rotation, without canola in the previous three to four years, had a higher average yield than those who did. None of the top group planted canola on canola stubble, while 15 per cent of the low group did.

Table 9. Guide to Field Selection for Canola Crops

Crop Before Canola	Wait Period	Remarks
Barley, Canaryseed, Rye grass, Oats, Wheat	0	No diseases in common. Can be grown the year before or after canola. Control stinkweed, mustard, volunteer canola and other problem weeds in these crops. Keep in mind herbicide residue carryover.
Buckwheat	1 year	Volunteer buckwheat growth may cause serious competition to a following canola crop.
Corn	1 year	Where atrazine was used for weed control, if a non-triazine canola is planned to be grown.
	0	Where triazine canola varieties grown.
Fababeans, Flax, Field Peas, Potatoes, Sweet clover, Red clover, Alskie	1 year	Common diseases. Rhizoctonia and Fusarium root rot. A low risk of Sclerotinia for fababeans flax, field peas and sweet clover.
Alfalfa, Soybeans	2 years	Common diseases. Rhiizoctonia and Fusarium root rot and Sclerotinia.
Sugar beets	2 years	Canola is a host crop to the sugar beet nematode and should not be grown 2 years before or 2 years after sugar beets.
Sunflowers, Field Beans, Lentils, Mustard	3 years	Common diseases. Rhizoctonia and Fusarium root rot and Sclerotinia. Mustard is a contaminant of canola; therefore, control volunteer mustard in the wait period.
Canola	3 years	Canola should not be grown on the same field more often than once in 4 years to prevent the buildup of diseases, insects and weeds

SEED SOURCE

The pedigree seed system, used in Canada to multiply seed of a variety from the plant breeder over a few generations, helps maintain the genetic makeup of the variety. Certified seed of a variety suited to the location will ensure that the seed you use is clean, true to variety, contains only low levels of weed seeds and seed-borne diseases, and will produce a high yielding crop with the canola quality demanded by the market place. **Over 90 per cent of the top group used pedigree seed, compared to only 60 per cent of the low group.**

DATE OF SEEDING

The time of seeding canola should be based on a combination of calendar date and soil temperature.

Soil temperatures in the spring vary from location to location and from year to year. The soil at the time of seeding should have a high enough temperature to provide rapid germination and emergence of a high per centage of the seed sown. Soil temperature has a great influence on the per centage and speed of germination, emergence and early leaf development.

Research at the University of Alberta found that B. napus varieties had a much higher per centage germination at low temperatures than B. campestris varieties (Table 10). Unlike these studies under controlled conditions, the speed of germination and emergence in the field would be slower by at least four to five days at 3°C, and about one to two days at 9°C. Soil temperatures can be determined for any field by taking the average of readings with a soil thermometer inserted at seeding depth at 8:30 a.m. and at 4:00 p.m. A good soil temperature for seeding both species of canola is 10°C. Soil temperatures above 10°C result in high germination, quicker emergence and rapid leaf development. **In the survey, the highest yields occurred where canola emerged in up to five to seven days.**

Research has shown that the highest average yields with the least year-to-year variations occurred in southern Alberta when both *B. napus* and *B. campestris* varieties were sown in early May (Figure 8). Significant yield reductions occurred with later plantings.

In central Alberta, the highest average yields with the least year-to-year variations for *B. napus* occurred with planting dates in the first two weeks of May, while *B. campestris* varieties required planting in mid May (Figure 9).

In northern Alberta the highest average yields, with the least year-to-year yield variations for *B. napus* varieties, occurred with early May seeding dates, primarily because of fall frost damage at later dates. If the frost damaged years were removed, then the best yields, shown by the light shaded areas in Figure 10, were from a mid-May seeding date. This implies that *B. napus* varieties respond better to the soil conditions at this time, and it is only the high risk of frost damage that necessitates earlier seeding. Therefore, *B. napus* varieties should be seeded in early to mid-May (May 10 up to as late as May 20) in the Peace River area to minimize frost risk. The highest average yields with the least year-to-year yield variations in *B. campestris* varieties were from mid to late May seeding dates.

In southern Alberta, plant according to the calendar date. In the more northern growing areas, soil temperatures provide a good guideline; however, waiting for warmer soil conditions increases the risk of fall frost damage, therefore, keep calendar dates in mind to ensure adequate days to mature.

Early sown canola takes longer to mature than later sown canola. The faster maturity of later-sown canola does not compensate entirely for the later seeding dates. The actual calendar date for maturity of late-sown canola is later than that of early-sown canola (Table 11). **In central Alberta the survey showed that more of the top group seeded their *B. napus* varieties in the first two weeks of May, and their *B. campestris* after May 15 but before May 30.**

Figure 10. Temperature Effects on Germination and the Number of Days to 50% Germination

Species and Characteristics	Temperature °C					
	2	3	5	7	9	15
B. napus						
Total % of germination	91	94	96	88	90	91
Days to 50% germination	13	9	6	4	3	2
B. Campestris						
Total % germination	34	67	88	78	90	95
Days to 50% germination	14	10	6	4	3	2

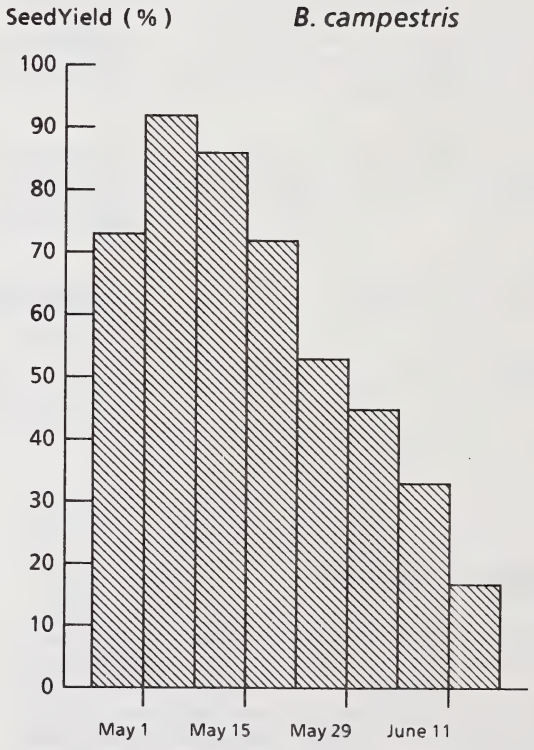
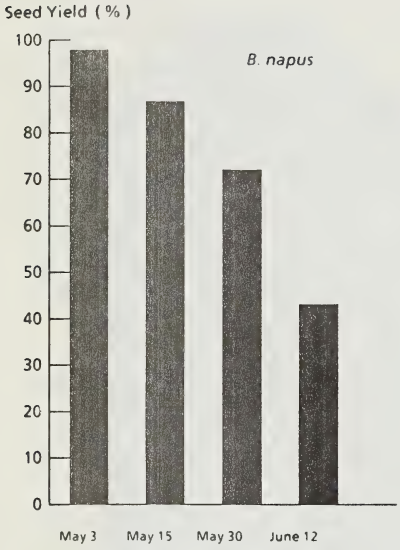
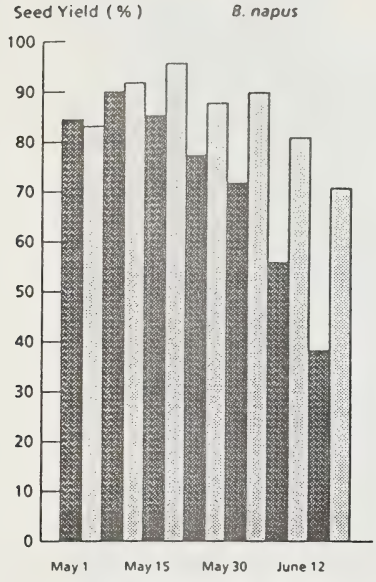
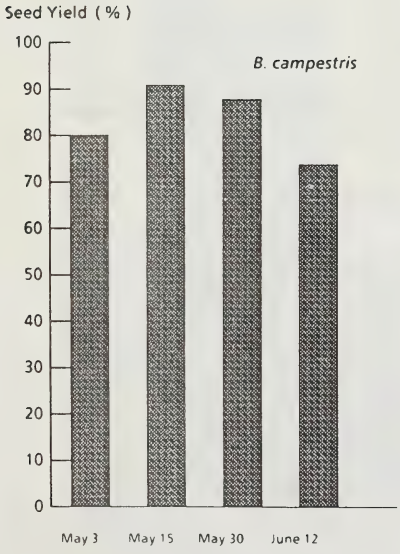


Figure 8. Average yields for data of seeding (Lethbridge).







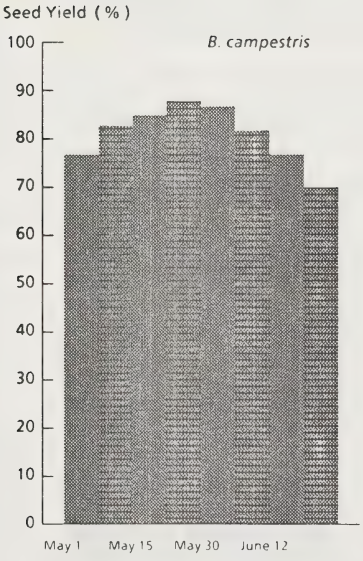


Figure 9. Average yields for dates of seeding (Edmonton).

Figure 10. Average yields for dates of seeding (Beaverlodge).

RATES OF SEEDING

Canola is a very flexible crop in that variations in seeding rate, or plant populations over relatively wide ranges, normally have very little effect on the final yield (Figure 11). The general recommended seeding rate for *B. napus* varieties is 5 to 7 lb/ac in south and central areas, and in northern Alberta, 5 to 8 lb/ac on fallow, and 8 lb/ac on stubble. The rate for *B. campestris* is 4 to 6 lb/ac in south and central areas, and in northern Alberta, 5 to 8 lb/ac on fallow, and 8 lb/ac on stubble.

With above-average seedbed and climatic conditions, about 60 to 80 per cent of the seed will normally produce viable plants in most areas except the Peace River region, where this would likely be 40 to 60 per cent on summerfallow and lower on stubble. The seeds which do not germinate and emerge are mechanically stopped by the soil or killed by disease. Under average conditions, about 40 to 60 per cent of the seed sown will produce plants in most areas except the Peace River region where only 20 to 40 per cent of *B. campestris* and 25 to 30 per cent of *B. napus* seeds can be expected to produce plants.

B. napus seed has an average of about 115,000 seeds per pound while *B. campestris* seed averages about 190,000 per pound. A 5 lb/ac seeding rate of *B. napus* would place about 13 seeds per square foot. Under conditions where only 40 per cent of the seed produces plants, about 5 plants per square foot would result which may not be a high enough density to hit top yields. For these conditions, the higher seeding rates will assure at least the minimum plant population required. Growers should aim at establishing plant populations of 7 to 17 per square foot. With a 6-in. drill row spacing, this would require a stand of 11 to 25 plants per yard of drill row.

Table 11. Dates of Seeding and Swathing Dates

Dates of Seeding	Range of Dates of Swathing at: Edmonton	Beaverlodge
B. napus		
May 1	Aug. 27-Sept. 13	Aug. 18-Sept. 14
May 15	Sept. 10-26	Sept. 1-19
May 30	Sept. 12-26	Sept. 13-Oct. 2*
June 12	Sept. 16-26	Oct. 5-25*
B. campestris		
May 1	Aug. 9-14	Aug. 5-18
May 15	Aug. 12-17	Aug. 11-29
May 30	Aug. 21-31	Aug. 16-Sept. 13
June 12	Aug. 29-Sept. 9	Aug. 31-Sept. 30

Results from the survey showed that the top group adjusted their seeding rates to match conditions and sowed a much higher per centage at the recommended rates for both species than did the low group. Over 75 per cent of the top group achieved plant populations of 9 to over 20 plants per square foot, compared to 53 per cent of the low group who achieved plant populations of between 3 to 9 plants per square foot.

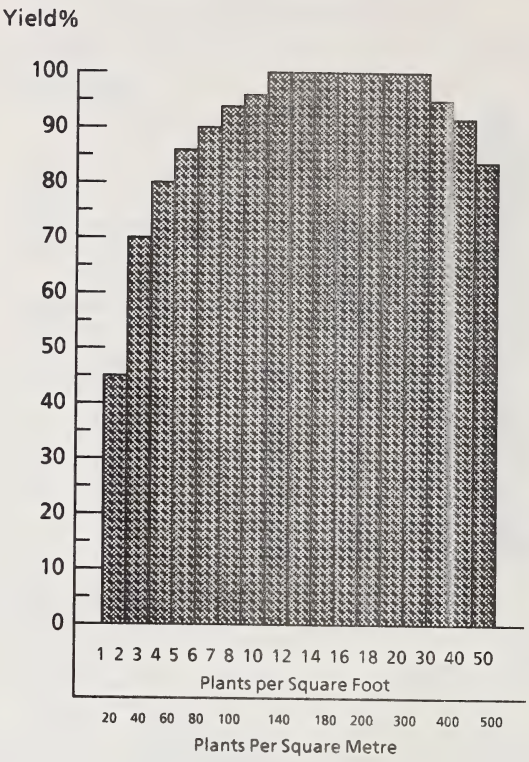


Figure 11. Yield response to plant population.

SEEDING DEPTH

Seeding depth greatly influences the number of seedlings that emerge and their rate of development. Canola seed sown 0.5 to 1 in. deep, into a firm, moist, warm seedbed germinates rapidly with a high per centage of emergence (Figure 12). Deeper seeding results in poor emergence; reduced root, seedling and plant growth; delayed maturity; seedling disease, and reduced yields (Figure 13). In this study at Beaverlodge, the per centage of emergence was highest at the 0.5 in. depth, but the speed of emergence was faster at the 1 in. depth, because of better soil moisture conditions. This resulted in higher yields. Shallow seeding on Grey-Wooded soils greatly improves seedling emergence. **The grower survey showed that 74 per cent of the top group planted their *B. campestris* varieties less than ¾ in. deep, compared to only 36 per cent of the low group. The top group tended to sow their B. napus varieties deeper than the low group mainly because they used more air seeders and hoe drills.**

ROW SPACING

Under most conditions in the canola growing areas, the normal 6 to 7 in. row spacing is adequate to obtain high yielding crops. However, research at Beaverlodge indicates yield increases with narrower row spacings. These results support those growers who report higher yields from double seeding at right angles or tandem drill hook-ups, with the second drill offset behind the first. These growers report much faster stand establishment and better competition against weeds. It is interesting to note that on fields double seeded, with the second at right angles to the first, growers observed the second seeding emerging at least two days sooner than the first. This was the result of a firmer seedbed and better depth control for the second seeding. Some growers who pack the seedbed with a full drill, and then seed the field, also achieve a firmer seedbed, better depth control, and rapid germination and emergence.

SEED DRILLS AND PLACEMENT

If properly operated and adjusted, most seeding equipment that places canola seed into the required environment will provide adequate stands of canola. The double disc press drill is probably the most satisfactory and consistent method on most soil types for placing the seed into moisture at a uniform shallow depth when operated on a good seedbed (Table 12). On heavy soils, where clay sticks to the press wheels of a press drill, or on soils which tend to pulverize and crust, the double-disc end wheel drill is better. The drill places, and only partially covers, the seed so it must be followed with drag chains or harrows. The use of hoe drills or hoe drills with attached rod weeders minimizes spring seedbed operations and loss of seedbed moisture. Shallow seeding is difficult. Air seeders require careful adjustment and operation due to irregular seeding depth, especially on unlevel soil surfaces and loose seedbeds. Shallow seeding at the depth required for canola is difficult with heavy-duty cultivator air seeders.

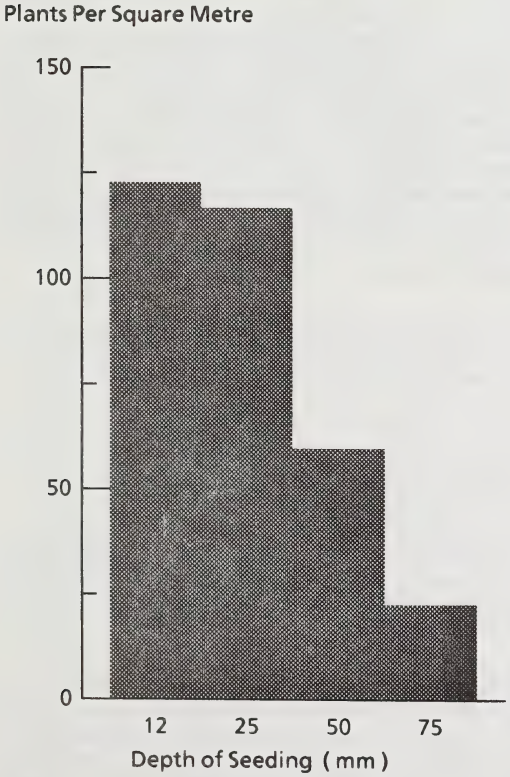


Figure 12. Plant population of canola at four seeding depths.

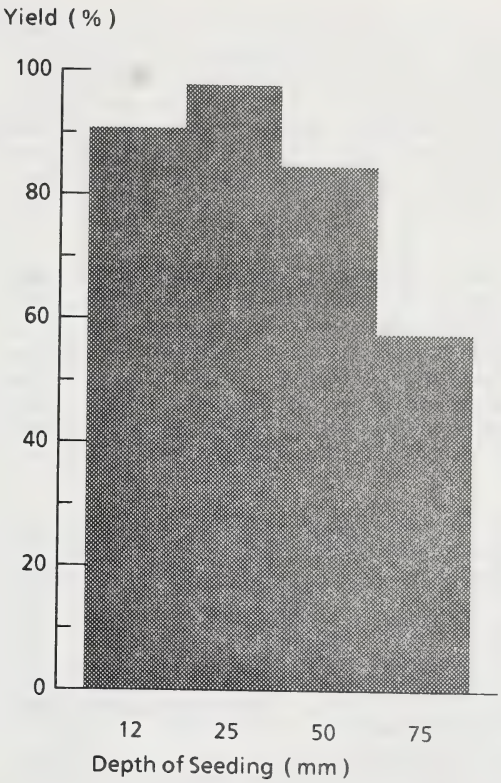


Figure 13. Per cent of highest yield of canola at four seeding depths.

Broadcast seeding can be successful, but only if soil moisture conditions are ideal, and the seedbed is firm before seeding and incorporating. Seeding canola by aircraft onto very wet or snow-covered fields is not recommended because it is seldom possible to cover the seed adequately, or soon enough, by harrowing or cultivating, to avoid losses. For broadcast seeding, the seedbed should be well prepared.

Harrow-packing, vibrashanking with harrows and packers, should then be done to cover the seed as soon as possible after broadcasting. Harrowing alone does not pack well enough to ensure germination in most cases. Many growers using broadcast seeding have reported that, where seedbeds dried up, only a small per centage of seeds germinated initially. This was followed by a heavier germination three to four weeks later, when a rain occurred, resulting in very uneven growth, flowering and maturity.

The survey showed that a large majority of the top group used double-disc press drills for seeding *B. campestris*, but that air seeders and hoe drills performed as well or better for *B. napus*. Survey results showed that a high per centage of the top group using air seeders and hoe drills had harrows and packers attached, or harrowed or used a harrow-packer combination after the seeding operation. The end results of stand establishment practices showed that:

- **More than twice as many of the top group achieved a uniform stand with a high plant population that was fast and vigorous growing at the seeding stage.**

Table 12. Seeding Method and Yield in *B. napus*.

Seeding Equipment	Yield kg/ha (bu/ac)	Plants per Square Metre (sq ft)
Double-disc press drill	2035 (36)	95 (9)
Hoe press drill	1984 (35)	46 (4)
Air seeder followed by harrows, and harrows and packers	1926 (34)	58 (5)

FERTILIZER REQUIREMENTS OF CANOLA

The total amount of plant nutrients removed from the soil by canola depends on the yield of the crop - the greater the yield, the greater the amount removed. Maximum yields of high quality canola cannot be obtained without adequate fertilization if the crop is grown on soils deficient in essential elements. However, fertilization alone will not increase yields or quality of canola if other management inputs are not at a high level. Nor will fertilization increase yields if the added nutrients are not required. Therefore, the most successful fertilizer program will be based on a knowledge of the soil's nutrient status combined with optimum fertilizer and plant management practices.

SOIL TESTING

A soil test is the most accurate means of determining the soil's nutrient status. Follow the correct soil sampling procedures to ensure the analysis results accurately reflect the nutrient status of the field soil.

- Use proper equipment and supplies.
- Sample at the proper time of year - in the fall after the soil temperature drops to 5°C (generally after October 1).
- Obtain samples from the correct soil depths.
- Take samples fully representative of average field conditions.
- Handle soil samples properly.

Fertilizer recommendations are based on the results of the laboratory analysis and on the nutrient requirements of the crop to be grown. Recommendations on time and method of application are also included. The most common limiting nutrients are nitrogen and phosphorus, while some potassium and sulphur deficiencies may also occur in particular areas and soil types.

The nutrient requirements of canola, in comparison to wheat and barley, are shown in Table 13.

NITROGEN

Canola has high nitrogen requirements. Large amounts are removed from the soil by canola (Table 13). More than half of the nitrogen is removed with the seed crop; however, considerable amounts of nitrogen are returned to the soil when the straw is incorporated.

Canola is very sensitive to nitrogen fertilizers applied with the seed, especially where the seedbed is relatively dry. Generally, the rate of nitrogen should be limited to a maximum of 10 lb/ac when placed with the seed. To avoid germination injury, nitrogen fertilizer should be broadcast-incorporated, side-banded below and to the side of the seed, or deep banded. At high rates of nitrogen, on medium textured soils particularly, a 1 in. separation of seed and fertilizer may not be sufficient to prevent harmful effects on germination, especially when urea is used.

Canola response to applied nitrogen fertilizer will depend on when and how the fertilizer is applied, and moisture available to the plants during the growing season. Applied nitrogen may be lost to leaching, volatalization, denitrification and weeds. Low soil moisture restricts the benefits of applied nitrogen fertilizer on canola yields; however, the full effect of favorable moisture conditions cannot be realized until adequate nitrogen has been applied to the canola (Table 14). A strong interaction occurs between nitrogen and water. Together these two factors resulted in a 34 bu/ac yield increase, nearly double the sum of the increase due to the two factors separately (18 bu/ac). Neither water alone nor nitrogen alone will produce high canola yields.

Banding is the best method of applying nitrogen. Banding nitrogen at 3 to 4 in. greatly reduces the risk of volatile nitrogen losses. Broadcast and incorporated applications in the spring are as effective as spring banding applications when early growing season rainfall is favorable. Under dry conditions, band placement is usually more effective than broadcast placement.

Table 13. Nutrients Used By Canola As Compared To Wheat Or Barley

Crop	Crop Part	Nitrogen (N)		Phosphorus P_2O_5		Potassium K_2O		Sulphur	
		kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac
Wheat	Seed	67	60	27	24	18	16	5	4
2690 kg/ha	Straw	28	25	6	5	54	48	7	6
(40 bu/ac)	TOTAL	95	85	33	29	72	64	12	10
Barley	Seed	67	60	25	22	22	20	6	6
3226 kg/ha	Straw	34	30	9	8	75	67	7	6
(60 bu/ac)	TOTAL	101	90	34	30	97	87	13	11
Canola	Seed	74	66	36	32	18	16	13	12
1960 kg/ha	Straw	44	39	16	14	75	67	10	9
(35 bu/ac)	TOTAL	118	105	52	46	93	83	23	21

The survey showed that all of the top growers banded their nitrogen fertilizer on stubble land with 60 per cent applied in the fall, whereas 67 per cent of the low group banded their nitrogen on stubble land, and only 43 per cent applied it in the fall. On stubble the top group applied an average of 77 lb/ac of nitrogen, compared to 55 lb/ac by the low group. The top group were more aware of their soil conditions, that is, fertility level, pH and organic matter, than the low group. With this information, the top growers could more effectively determine what nutrients and in what quantities to apply to optimize yields. Anhydrous nitrogen was used by 90 per cent of the top group, whereas only 62 per cent of the low group used anhydrous. The top group applied their nitrogen in the fall because of:

- **Greater assurance of achieving the required seedbed for canola**
- **Fewer soil drying operations in the spring**
- **Reduced spring workload with less fertilizer to handle**
- **Earlier and more timely seeding because of time saved.**

Table 14. Canola Responses to Nitrogen and Water on Stubble (Average of 10 site-years)

	Canola Yield	
	kg/ha	bu/ac
Check - dryland	560	10
Adequate water - irrigation	1010	18
Dryland - adequate nitrogen	1120	20
Adequate water plus adequate nitrogen	2470	44

PHOSPHORUS

An adequate supply of soil phosphorus enables the plant to develop a strong, healthy rooting system in the early growth stages. The phosphorus requirements for good yields of canola are greater than those for wheat or barley due to the higher protein content of the seed (Table 13).

Canola generally responds favorably to phosphorus fertilizer on soils that are low in available phosphorus (Figure 14). The maximum response to nitrogen fertilizer cannot be obtained when phosphorus and other essential nutrients are in short supply. The response to added phosphorus fertilizer can also be limited if available soil nitrogen is at low levels (Figure 15).

The most efficient way of applying phosphorus is drilling it in with the seed. However, in some situations, where, after emergence, the weather turns dry, phosphorus placed with shallow sown canola seed can end up stranded in the dry surface layer where it is less available than in bands deeper in the soil. Also, it is recommended that no more than 20 lb/ac of phosphorus be placed with the seed under average moisture conditions. Under moist conditions, or in applications with a discer, airseeder or hoe drill, 28 lb/ac of phosphorus may be seed placed. Higher rates of phosphorus reduce seedling emergence and yield potential.

Where higher rates of phosphorus fertilizer are required, it can be banded away from the seed. This results in little damage to germination and emergence, and larger yields and response to considerably higher rates of applied fertilizer. Where nitrogen is also required, the phosphorus can be applied in the same band (double shooting). When nitrogen and phosphorus are placed together in a band they are usually more effective than when broadcast and mixed into the soil, especially in dry years (Table 15). The data show that phosphorus placed with the seed resulted in a further yield increase. Retaining some of the phosphorus fertilizer for seed placement may be beneficial on very low testing phosphorus soils, when surface moisture is good and when cool, wet conditions prevail in the spring.

The survey results showed that:

- **The top group applied 28 lb/ac of phosphorus on average to balance their higher nitrogen applications, whereas the low group applied 17 lb/ac of phosphorus.**

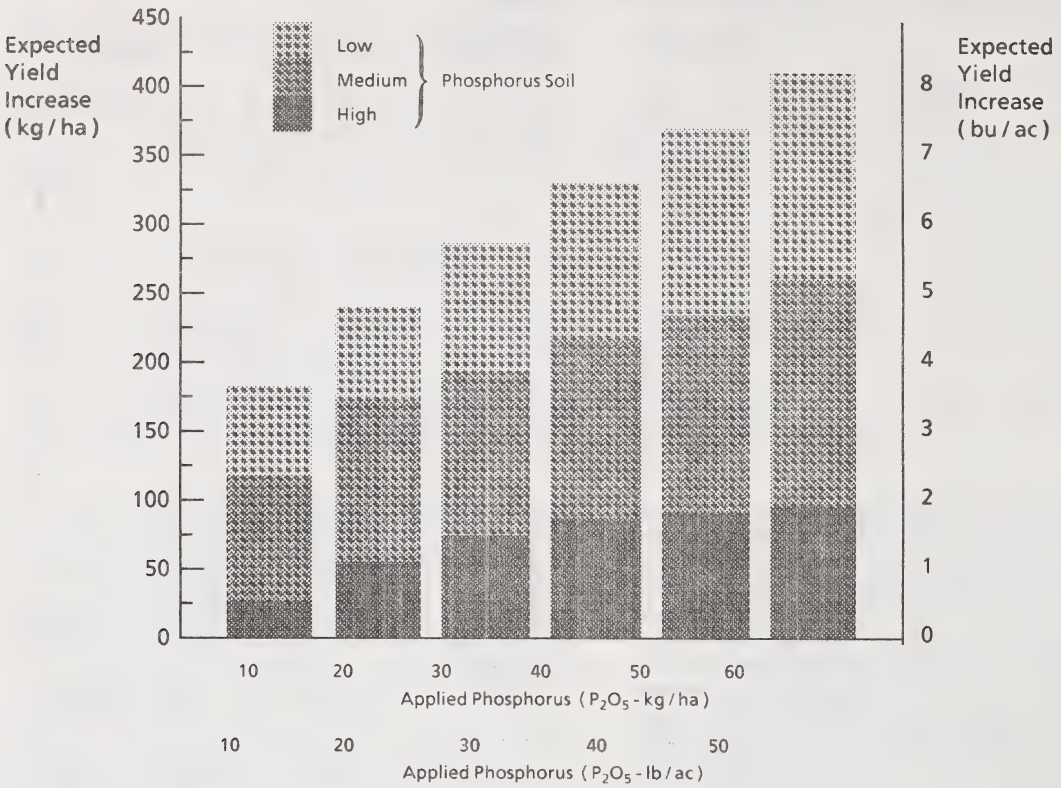


Figure 14. Expected canola response to phosphorus fertilizers as affected by the soil tests for phosphorus.

- **Phosphorus was mainly applied with the seed in the spring in a granular form. About 10 per cent of the phosphorus was deepbanded for all groups.**
- **Only a low number of growers used potassium (36%) or sulphur (18%).**

POTASSIUM AND SULPHUR

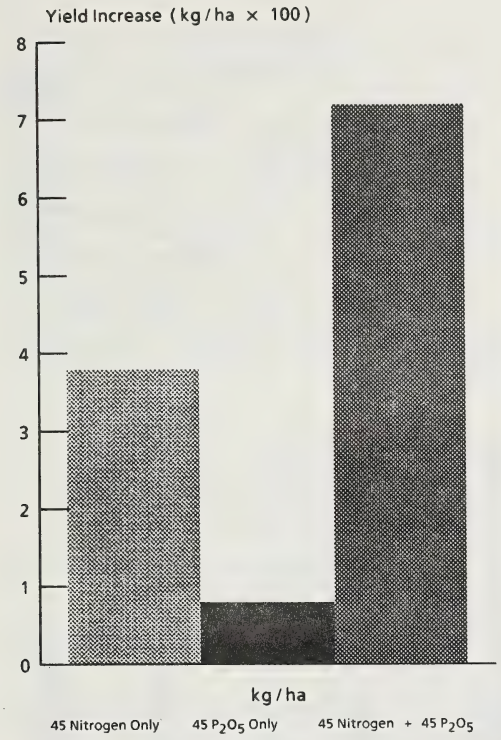
Most soils in Alberta, except sandy or organic soils, contain large amounts of potassium. Canola responses to potassium fertilizers are not large on soils with moderately low available potassium. However, on very deficient potassium soils, a marked yield increase may result from potassium fertilizer application. Test your soil to determine whether potassium or sulphur fertilization are required. Potassium fertilizer placed with the seed reduces germination and emergence. When potassium is required, some form of banding or broadcast-incorporation of the potassium fertilizer should be used.

Very large increases of canola have been obtained on sulphur deficient soils with the application of a sulphur fertilizer (Table 16). Sulphur in fertilizers, in the form of sulphate, is quite mobile and readily available to crops. Other sulphur fertilizers containing elemental sulphur usually require several months of warm moist soil conditions to be converted into a plant available form.

Table 15. Response of Canola to Different Placements of Nitrogen and Phosphorus Fertilizers

Placement	Yield of Canola kg/ha	bu/ac
No fertilizer	753	13.4
N broadcast + drill-in P_2O_5	1370	24.4
N band + drill-in P_2O_5	1954	34.8
N + P_2O_5 broadcast	1236	22.0
N + P_2O_5 banded	1909	34.0
N + P_2O_5 banded + drill-in 1/3 P_2O_5	2100	37.4

Note: N applied at 80 kg/ha
P_2O_5 applied at 30 kg/ha



The response of canola to nitrogen (N) and phosphorus P_2O_5 when applied singly or in combination on a black loam deficient in both nutrients.

Canola yield:
kg / ha / 100 × 1.78 = bu / ac

Figure 15. Response of nitrogen plus phosphorus.

Table 16. Canola Response to Sulphur

Fertilizer Applied	Yield Response Alberta kg/ha	Alberta lb/ac	Saskatchewan kg/ha	Saskatchewan lb/ac	Manitoba kg/ha	Manitoba lb/ac
No fertilizer	390	7	703	13	1011	18
NPK	89	2	693	12	281	5
PKS	581	10	981	18	1404	25
NKPS1	1800	32	1784	32	2033	36
NPKS2	1942	35	1881	33	2145	38

S1 = Low sulphur rates 22 to 25 kg/ha (20 to 22 lb/ac)
S2 = Higher sulphur rates 45 to 57 kg/ha (40 to 51 lb/ac)

WEEDS OF CANOLA

Weeds are the most limiting factor in canola production. Weeds that cause problems in canola are the perennial types, shade tolerant weeds, and tall growing, early germinating weeds such as wild oats. Among the more troublesome weeds that are not controlled by herbicides in a normal canola crop are the closely related cruciferous weeds:

- Wild mustard
- Stinkweed
- Shepherd's purse
- Ball mustard
- Flixweed
- Wormseed mustard
- Hare's-ear mustard
- Common peppergrass

Other hard or expensive to control weeds in canola are:

- Canada thistle
- Cleavers
- Lady's thumb
- Sow thistle
- Green smartweed
- Quackgrass

Weeds result in significantly reduced yields through competition for light, moisture and nutrients. When any of these factors are limiting, especially light at the early growth stages, canola yields are reduced. Yield losses depend on the kind of weed, weed populations, time of emergence of weeds and crop, and the timing of control.

As shown in Figure 16, the estimated yield losses are greatest for populations of sow thistle and Canada thistle, followed by wild mustard, volunteer barley, wild oats, volunteer wheat and, the least competitive, tartary buckwheat. Canola yield losses from wild buckwheat are probably similar to those from Tartary buckwheat. Canola yield losses due to smartweed, hempnettle and lamb's-quarters may be higher than Tartary buckwheat due to the taller growth habits of these weeds.

Canola is not a strong weed competitor in the early growth stages, as it is slow growing and slow to cover the ground. The time of emergence of the weeds will have a major effect on crop yield losses. Consider this and weed numbers when deciding to spray (Table 17).

Table 17. Effect Of Time Of Emergence Of Volunteer Barley On Tobin Yields

Barley Emergence* Relative to Canola	Yields Bu/ac Canola	Barley
14 days prior	5.5	86
7 days prior	6.4	86
0 same day	15.7	72.5
7 days later	30.4	45.6
14 days later	35.4	20.6

** 150 barley seeds/m²*

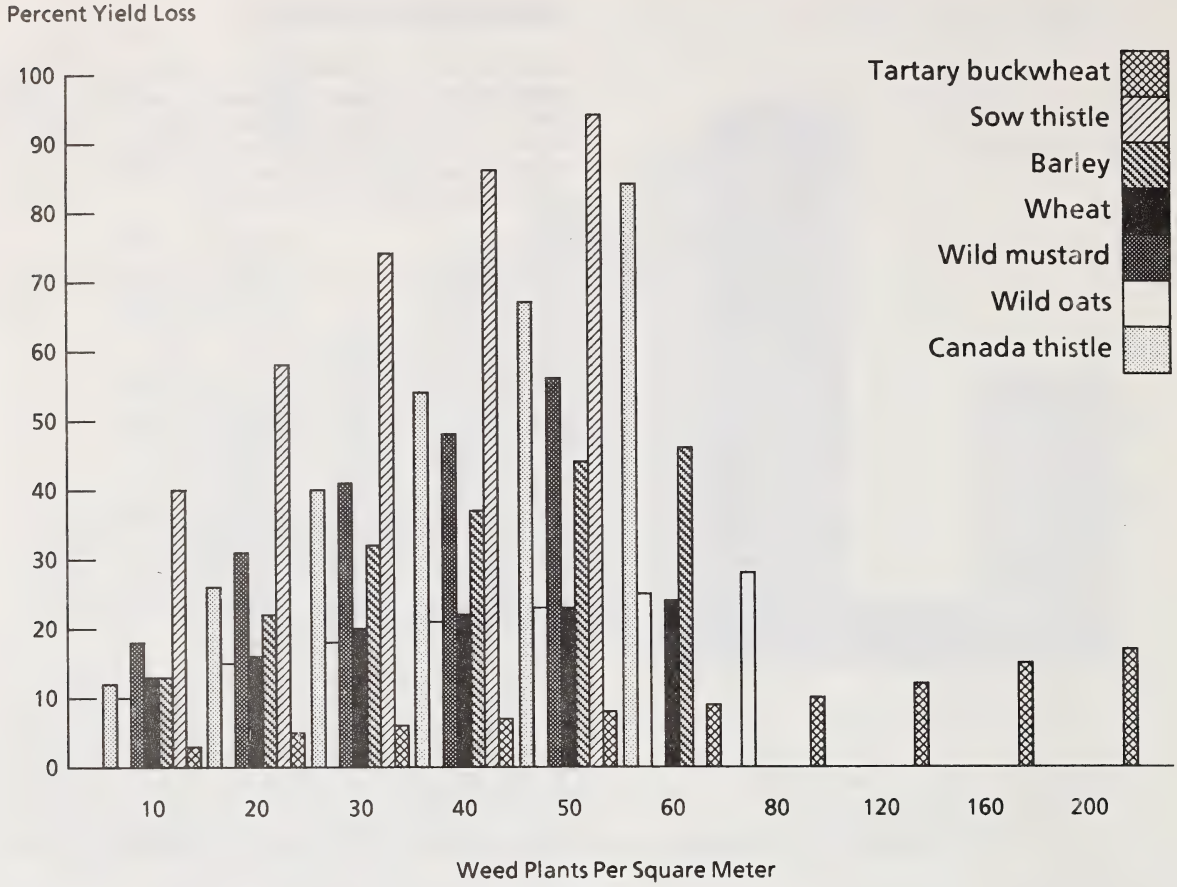


Figure 16. Estimated yield losses (%) from weed competition in Canola.

If weeds emerge before the crop, there are greater yield losses than if the crop emerges first. After canola becomes established with a large rosette, there are few weeds that can survive the intense competition. Weeds emerging 7-10 days after the crop have a greatly reduced ability to compete with the crop.

Weeds should be controlled early when the crop is susceptible to competition (Table 18).

Table 18. Effect On Canola Yields Determined By When Wild Oats Were Controlled

Wild Oats Removed Days After Emergence*	3-Year Average Yield Bu/ac	% Yield
Weed free	47	100
7	41	87
14	41	87
21	40	85
30	35	75
40	29	62
Weedy to harvest	25	53

** 150 wild oats/sq yd*

Besides causing significant yield losses, weeds can:

- Increase dockage.
- As a host plant help increase insect and diseases.
- Increase the need for cultivation and chemical control practices.
- Increase heating and spoilage from green weed seeds in storage.
- Reduce grades and quality.

There are five fundamental methods of controlling weeds in canola.

Preventive Measures:

- Use weed free seed.
- Use only clean, weed-free machinery and hauling facilities.
- Restrict animal movement from weedy fields to clean fields.
- Handle weedy manure in a manner that eliminates spread of viable weed seeds.
- Where possible, control or restrict wind and water movement from weedy to weed-free areas.

PHYSICAL CONTROL MEASURES

- Use tillage that will bury weeds, expose them to frost or drying, or wound them to allow for entry of decay-causing organisms.
- Hand weed smaller patches of select weeds.
- Mow where tillage is impractical.
- Burn weeds prior to maturity.
- Pasture and graze to prevent seed formation.
- Mulch small weed patches with clean straw, manure or polyethylene film.

CULTURAL CONTROL MEASURES

- Use crop rotations that may include fallow, forage crops, row crops or fall-sown cereals, to take advantage of weaknesses in the life cycle of existing weeds and thereby eliminate them.
- Use plant competition to your advantage. Any measure that enhances vigorous crop growth helps to control weeds.
- Adjust timing of cultural operations. Delayed seeding has traditionally been used to control certain weeds; however, with the herbicides now available, this is not economical.

BIOLOGICAL CONTROL MEASURES

This technique has not yet been perfected to the point where it has any major value to individual canola producers. Control agents are usually insects or diseases which attack only one specific weed.

CHEMICAL CONTROL MEASURES

- Herbicides should be used in combination with good preventive, cultural and physical control measures.
- The only major broadleaf herbicide available is the soil-applied trifluralin.
- Lontrel provides excellent control of Canada thistle, scentless chamomile and wild buckwheat, with some top growth control of sow thistle.
- Several herbicides are available for grassy weeds and volunteer cereals.
- When herbicides are used as directed, they usually do a good job of controlling the weeds that are susceptible.
- Most failures to properly control weeds are the result of failing to follow the label directions.

For a complete list of available herbicides, how they work and how they should be applied, obtain the publication *Guide to Crop Protection in Alberta* from your district agriculturist.

From the survey of growers in central Alberta, the eight most troublesome weeds were Canada thistle, wild oats, stinkweed, chickweed, hemp nettle, sow thistle, quackgrass and volunteer cereals. This listing was the same for the top and low group. The differences noted between weed control measures used by top and low producers were:

- **In the top group, 95 per cent achieved greater weed control at the seedling stage and throughout the growing season, compared to the low group at 50 per cent.**
- **The top group were more aware of their weed problems (types and numbers).**
- **Top growers achieved better weed control through greater and better use of herbicides.**
- **A high per centage (40%) of the growers in the survey did not incorporate their trifluralin satisfactorily. Many incorporated the herbicide either too shallowly or too deeply, or only with a single incorporation.**

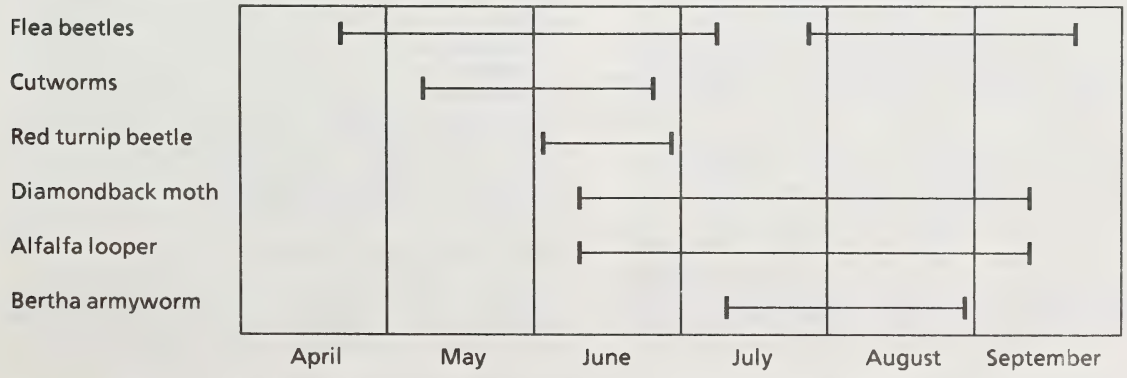
INSECT PESTS OF CANOLA

From emergence to harvest, canola crops are attacked by a number of insect pests. Fields should be examined daily during the seedling stage and regularly thereafter. By recognizing which insects found in the crop are capable of causing major losses, and which are of no economic importance, you will avoid unnecessary and costly treatments. The timely application of insecticide, combined with cultural controls, will avert major damage.

For a complete list of available insecticides, obtain the publication, *Guide to Crop Protection in Alberta,* from your district agriculturist.

Economic thresholds are given for important pests where known, however, they should only be considered as rough guidelines. Many factors such as crop price, chemical costs, growth stage and environmental conditions also affect crop-insect relations. Cultural controls are often cheap and effective alternatives to chemical controls.

The following diagram is a rough guide to illustrate when the damaging stages of the major canola pests are found in the crop.



FLEA BEETLES

Description and Life History

Flea beetles have become the major insect pest throughout the canola growing areas of Alberta, primarily because of the greatly expanded acreage of this crop in recent years. The two most common species causing damage are the crucifer flea beetle and the striped flea beetle. Flea beetles are very small, 2-3 mm long, black or black with yellow stripes, and capable of jumping. At temperatures above 20°C they can also fly and distribute themselves throughout the crop. Larvae are soil inhabiting, white, six-legged worms which are rarely seen. Adult beetles overwinter in soil and leaf litter in the headlands, poplar groves and similar sheltered locations, becoming active in late April or early May, depending on temperature. At first they feed on weeds, mostly cruciferous, but move into canola once the seedlings emerge. Adults mate and lay eggs in the soil in May and June, dying in late June or early July. Larvae feed below ground on the roots of host plants, apparently causing little damage. They pupate in early July and emerge as adults in late July and early August. Most of these adults hibernate by mid September. There is only one generation a year.

Damage, Sampling and Economic Threshold

Most damage occurs to seedling canola between late May and mid June and can be recognized as characteristic 'shot-holes' in the cotyledons and leaves. Occasionally, large populations of new generation adults will attack late-maturing canola pods in late summer. Feeding activity and damage are enhanced by warm, dry, sunny weather. If the crop has good growing conditions and adequate soil moisture, it can often outgrow a moderate flea beetle attack and compensate for the damage with no loss in yield. Because of the complexities of the interaction of crop, weather and flea beetle populations, no economic threshold has been established; however, there is usually no cause for concern if damage up to the 6-leaf stage remains below 50 per cent under good growing conditions. Under dry conditions, where seedlings are already under stress, a lower per centage of leaf loss may result in economic yield reductions. Check fields daily during the seedling stage.

Control

Cultural: Control cruciferous weeds and volunteer canola to starve out early spring flea beetle populations. Alternatively, leave a trap strip of volunteer canola near overwintering sites in the spring, and cultivate the remainder of the field. This will force the beetles to move to the trap strip where they can be sprayed. Sow at a higher seeding rate if the population was high in the area the previous fall.

Chemical: In problem areas, use preventive seed treatment, followed by a post-emergent foliar spray if necessary.

Lindane seed treatment will protect seedlings for about four days after emergence, while Furadan or Counter granules provide protection for 2 weeks. Use a sticker, such as a vegetable oil, with lindane powder formulations at 10 fl oz per 100 lb seed, mixing according to label instructions, and sow within one week of treatment. Plant seed mixed with granules immediately.

BERTHA ARMYWORM

Description and Life History

The bertha armyworm is periodically a major pest of canola throughout Alberta. The adult moth is a pale brownish green with a white spot and apical band on each forewing. It emerges from an overwintering pupa in the soil between mid June and mid July. Each female deposits up to 100 eggs in batches on the undersides of host leaves (canola, flax, sweet-clover, potatoes, etc.). When small, larvae are green with a pale yellowish stripe along each side. When full grown (40-50 mm) most are velvety black but some are green or brown. They feed on leaves and pods until mid to late August. There is only one generation a year. Larvae are subject to many diseases and parasites which regulate their abundance from year to year.

Damage, Sampling and Economic Threshold

Larvae chew irregular holes in foliage, however, most damage is done when mature larvae feed on the pods. Crops should be checked from mid July onwards, particularly late-maturing crops. Sample for numbers by walking at least 50 paces into the crop, beating a square metre area every 10 paces to dislodge larvae onto the ground where they can be counted. An average of 17 to 20 larvae per square metre will usually justify treatment.

Control

Cultural: Cultivate in fall to expose pupae to freezing, parasites and predators.

Chemical: Apply one of the recommended foliar insecticides.

DIAMONDBACK MOTH

Description and Life History

The diamondback moth does not overwinter in Alberta but is carried in on winds from the United States each spring. The number of spring migrants and their establishment is weather dependent, so infestations are not easily forecast. By late summer, most canola fields are infested to some extent. The adult moth is a small, narrow, brown insect with pale, diamond shaped markings along the back wing margin. Eggs are scattered on either side of the leaves of cruciferous plants. The first small green larvae are evident by mid June, and act as leaf miners, later becoming open feeders. The larvae wriggle violently backwards if disturbed and drop from the leaf by a silken thread. They are 8 mm long when fully grown and pupate on the plants in white, open lace-like cocoons. There are at least three overlapping generations a year; thus all stages may be found on the plants at the same time.

Damage, Sampling and Economic Threshold

Larvae chew irregular holes in the leaves and may feed on flowers and debark pods and stems. Sample by beating square foot areas while walking into the field, and count larvae on the ground. An average of 30 or more larvae per square foot

may warrant control, especially in late maturing crops.

Control
Cultural: Cultivate in early spring to destroy weed hosts.

Chemical: Apply one of the recommended foliar insecticidal sprays.

ALFALFA LOOPER

Description and Life History
The alfalfa looper is a sporadic pest of canola which also attacks forage crops and other vegetables and ornamentals. Found throughout Alberta, it may overwinter in the pupal stage, though many early summer moths are migrants from the United States. There are two or three generations a year. Adult moths have silver grey and brown forewings with a characteristic pale gold central mark. Females deposit 150-200 eggs either singly or in clusters on host plants. Larvae reach 35 mm in length and are pale or dark green with several thin white, wavy lines running down their backs. Their looping motion is due to the small number of abdominal "legs." Larvae can be found from mid June to September as generations overlap. They pupate in wooly cocoons on the plants, often in the flower heads. Viral disease, parasites and predators help control the late season generation.

Damage, Sampling and Economic Threshold
Damage occurs through defoliation and clipping of flowers and immature seed pods. No economic threshold has been established, however, it is probably similar to that of the bertha armyworm, and when combined with heavy defoliation or flower and pod clipping, control may be warranted.

Control
Cultural: Avoid growing canola near alfalfa.

Chemical: Apply one of the recommended foliar sprays.

RED TURNIP BEETLE

Description and Life History
The red turnip beetle feeds on cruciferous plants in the parkland areas of the province, and the Peace River region. Populations fluctuate considerably from year to year and occasionally build up to economically damaging levels. The species overwinters in the soil as reddish brown eggs which hatch in early spring. The black, rough-skinned larvae feed at night on volunteer canola seedlings and cruciferous weeds. In three to four weeks they pupate in the soil. Adults emerge during the first three weeks of June and immediately seek out canola seedlings and other host plants. They are 3 mm long, red, with three black stripes on the back. During July they burrow into the soil to escape hot weather and re-emerge in August to mate and lay eggs. There is only one generation a year.

Damage, Sampling and Economic Threshold
Most damage is done by adult beetles moving into seedling canola and stripping all the leaves from the plants. Unless canola is sown on canola (not a good practice), invasion is usually along one edge of the field and follows cultivation of a nearby field of volunteer canola or weedy stubble, forcing migration in search of food. Check such fields before cultivating, and if infested, be prepared to apply a control chemical to the invaded edge of nearby canola fields.

Control
Cultural: In fields known to have red turnip beetles, cultivate in late fall or early spring to bury eggs and reduce larval survival. Cultivation also removes cruciferous weeds and volunteer canola.

Chemical: Apply one of the recommended foliar insecticides.

RED-BACKED CUTWORM

Description and Life History
The red-backed cutworm is widespread in Alberta and feeds on many crops besides canola, particularly cereals. Populations fluctuate from year to year. Eggs laid in late fall in loose, dry soil in weedy stubble or summerfallow hatch the following April. Larvae feed on weeds and attack newly germinated crops. These night feeding cutworms are brown with two broad, dull, brick-red stripes along the back. They reach 38 mm in length by mid June and pupate in the soil. The adult moths emerge in August and September to mate and lay eggs. There is one generation a year.

Damage, Sampling and Economic Threshold
Young cutworms chew holes and notches in leaves, whereas older cutworms sever the stems at or just above the soil surface. Check the edge of bare areas for cut-off plants and sift the top 2 in. of soil around such plants for larvae. Damage is often patchy, occurring on hills and light soil areas, so that only limited spraying is required.

Control
Cultural: Keep fields in summerfallow free of weeds to discourage egg laying in August.

Chemical: Apply one of the recommended foliar insecticides.

DISEASES OF CANOLA

Diseases affect the pods, stems, leaves and roots of canola crops grown in Alberta every year. Occasionally this results in serious losses to the producer. Different diseases can attack the crop at any time from seeding to maturity. Disease severity varies with the year and location, and is greatly influenced by farming practices and environmental conditions. By learning to recognize canola diseases and identify those that are economically important, you can undertake disease management practices to reduce losses.

SEEDLING BLIGHT
Damping-off or seedling blight occurs throughout Alberta. The disease usually results in the death of only a proportion of

seedlings every year causing an insignificant reduction in plant density. However, in some years, the entire stand or large patches in the field may be killed and require reseeding. Seedling blight is most common when the crop is sown too deeply, or in cold dry soil, or both.

Cause
Various fungi, primarily *Rhizoctonia solani, Fusarium* spp. and *Pythium* spp., cause seedling blight.

Symptoms
Seed or young seedlings may rot in the soil and fail to emerge indicating pre-emergence damping-off. Plants may emerge then suddenly collapse, or emerge and stagnate in the seedling or 2-4 leaf stage even when growing conditions appear favorable. This stage of the disease is known as post-emergence damping-off or seedling blight. The stems of infected seedlings appear water soaked or constricted at and below the soil line, and may be discolored reddish brown. Although flea beetle damage may occur together with seedling blight, insect damage should not be mistaken for the disease if the seedlings are dug up and examined. Flea beetles do not cause the seedling stem to rot off or constrict at or below the soil line.

Disease Cycle
The causal fungi are soil-borne and may survive for years in the absence of a host. Plants may be attacked anytime from germination until the 2-4 leaf stage. Infection usually occurs before or shortly after seedlings emerge from the soil. Environmental conditions that reduce seedling vigor, like cool temperatures and deep seeding, favor the pathogens and disease development. *Pythium* is usually favored by cool wet soils, whereas *Rhizoctonia* and *Fusarium* may cause more damage in drier seedbeds.

Control
Cultural: Avoid seeding deeper than 4 cm into cool soils. Seeding 1-2.5 cm into a firm, moist seedbed when soil temperature is above 10°C will result in vigorous emergence and reduce the period of seedling susceptibility. Fertilizer placed with the seed may delay or reduce emergence. No more than 10 kg N/ha or 20 kg P_2O_5/ha should be placed with the seed.

Chemical: Seed treatment fungicide-insecticide combinations help protect the seedling during the emergence period and result in better stand establishment as shown in research trials conducted in Alberta. For a complete list of available seed treatments, consult Alberta Agriculture's, *Guide to Crop Protection in Alberta*, an annual publication.

STAGHEAD OR WHITE RUST

Staghead is a common disease of Polish canola varieties in Alberta. Yield losses as high as 20 per cent have been recorded in some severely affected fields. The disease appears to be more prevalent in northern and north central Alberta.

Cause
A fungus, *Albugo candida*, causes staghead or white rust.

Symptoms
White to cream colored spots (pustules) may appear on the underside of leaves from the seedling stage onward. The most conspicuous symptom is the presence of swollen, twisted, and distorted flowers and flower stalks. These "stagheads" are green at first, becoming hard, dry and brown later in the season. They may be covered with white pustules or a white mealy growth during periods of wet weather.

Disease Cycle
The pathogen overwinters as thick-walled oospores that may be carried in staghead debris with the seed or from stagheads infesting the soil. In the spring, zoospores germinate, following leaching by spring rains, and release 40 to 60 mobile zoospores that can infect young seedlings. Following infection, white pustules form on the underside of leaves. Pustules rupture to release chalk-like, air-borne spores that can spread the disease on the plant or to other plants causing leaf, stem and flower infections. Stagheads usually develop following infection of young flower buds. Overwintering zoospores form within stem blisters and stagheads, and infest the seed when the crop is combined.

Cultural Control
Rotate with non-susceptible crops such as cereals, and control volunteer canola and cruciferous weeds during the rotation. Stinkweed, marsh yellow cress and wild mustard may carry strains of the fungus that can affect Polish types of canola.

Resistant Varieties
The variety, Tobin, is the first Polish type of canola variety with resistance to staghead. Argentine varieties are immune to all races of the disease currently found in western Canada.

SCLEROTINIA STEM ROT (WHITE MOLD)

Stem rot occurs in all canola growing areas of Alberta. Recently it has been most severe in north central Alberta, particularly in the west. Yield losses of 15 to 40 per cent occur in heavily infected crops, but higher losses have been recorded. Wet weather and warm temperatures during the flowering period favor infection and disease development. Heavy and lodged crops suffer the greatest yield loss.

Cause
A fungus, *Sclerotinia sclerotiorum*, causes stem rot.

Symptoms
Pale grey stem lesions develop at or above the soil line or on upper branches and pods. Symptoms usually develop after flowering commences and are more common following periods of wet weather. Plants with girdled stems ripen prematurely and may stand out compared to green healthy plants. Stems on these plants appear bleached and tend to shred. Hard, black sclerotia or "sclerotes" may be found within infected stems, branches or pods. Sclerotia vary in size and shape. They may be small and spherical, about the size of canola seed, or elongate and cylindrical, up to 2 cm long.

Disease Cycle
The disease overwinters as sclerotia in the soil or as contaminants with the seed. Given suitable moisture conditions, sclerotia may germinate in two different ways. Sclerotia can germinate producing small, golf-tee shaped reproductive structures called apothecia. Apothecia produce ascospores that may be dispersed by wind currents up to a few kilometres from their source. Apothecia develop during periods of high soil moisture from late June onwards. Ascospore infection and disease development are greatest during periods of warm wet weather.

Alternatively, sclerotia can germinate to produce a cottony white mold that may infect plants at or near the soil line. New sclerotia are formed within infected stems, branches and occasionally pods. Sclerotia are harvested with the seed when the crop is combined; others fall to the ground infesting the soil.

Control
Cultural: Sclerotinia is a difficult disease to control because it infects over 360 species of plants including many crops and broadleaved weeds. As well, sclerotia may persist for many years in the soil in the absence of a host.

Allow at least four years between susceptible crops like canola, field peas, beans, lentils and clovers. Control volunteer canola and broadleaved weeds during the rotation. Cereals and grasses are immune to *Sclerotinia sclerotiorum*. Do not seed canola adjacent to fields that were heavily infected the previous year.

Use clean seed free of sclerotia; only a spiral cleaner will remove the small seed-sized sclerotia from canola.

Chemical: Significant and economic yield increases in Argentine type canola have been obtained with a systemic fungicide like benomyl (Benlate) and iprodione (Rovral) applied at the 20 to 30 per cent bloom stage. For further specific information on chemical control of this disease, contact your district agriculturist.

BLACK LEG
A mild or a virulent form of blackleg occurs in all canola producing areas of the province, but is rarely associated with any yield loss. However, a virulent or more aggressive form of the disease was found in Saskatchewan in 1975 and has now spread to isolated locations within Alberta. This strain of the disease has caused serious yield reductions of 10 to 50 per cent in Saskatchewan.

Cause
A fungus, *Leptosphaeria maculans*, causes blackleg.

Symptoms
Buff colored, round to irregular leaf spots that are dotted with numberous black fruiting bodies appear during the summer. Later in the season, superficial, white to grey-black lesions, typical of the mild strain, may occur at the base of the stem or on other above-ground plant tissues.

In contrast, the virulent strain of the fungus infects the plants much earlier in the season. Leaf spots may appear from the seedling stage onward, and stem infection before the 6 leaf stage is usually associated with serious yield loss. Following stem infection, a severe grey to black basal stem canker may develop, girdling the stem and killing the plant.

Disease Cycle
The fungus overwinters on crop stubble and within and on infected seed. In areas where the virulent strain is established, seed infection is of little importance to disease development. The infected seed, however, provides an effective means of long distance dispersal and is a likely method of introduction into areas which do not already have the disease.

Air-borne spores from infected stubble of previous crops initiate the primary infections in the field. White to buff colored leaf spots develop and, within them, numerous fruiting bodies that produce a second spore type. Spores from infected plants are carried by wind and rain splash and increase the disease on the plant and adjacent plants. Seeds produced within infected pods may be diseased.

Wild mustard (*Sinapis arvensis*) is the only important weed host of the virulent strain of blackleg.

Control
Cultural: Rotation is an important form of disease management. Severe yield losses from the virulent strain have only occurred where canola was planted on or adjacent to a field in which the disease had occurred the previous year. Ascospores are produced on infected stubble for at least two years or until the residue is decomposed. Burial of infected canola trash appears to be an effective method of control. Control volunteer canola and cruciferous weeds during the rotation.

Chemical: Seed treatments containing the systemic fungicides benlate or carbathiin will control the seed-borne stage of blackleg. A known seed source and seed treatment with fungicide is our defense against the spread of this disease in Alberta.

Resistant Varieties
All varieties presently available are susceptible to blackleg, however, resistant lines are being developed in a canola breeding program at Saskatoon.

BROWN GIRDLING ROOT ROT
This disease is a major problem in the Peace River region where some fields may have 80 to 100 per cent infected plants. Damage is usually greatest when wet soil conditions occur at the onset of flowering, followed by dry weather later in the season.

Cause
Rhizoctonia solani is the primary cause.

Symptoms and Disease Cycle
Light brown lesions develop on the taproot and lateral roots usually at or following the onset of flowering. Lesions become sunken and darker and may enlarge to girdle the taproot resulting in premature death of the plants. Girdled plants may have only a short stub of the taproot remaining and are subject to dessication and lodging. Losses are greatest when high temperatures and dry windy conditions follow root damage. Yield loss may exceed 50 per cent.

Cultural Control: None.

Chemical Control: None.

Resistant Varieties
Argentine type canola appears to have some resistance to this disease and should be grown where climatic conditions are suitable.

ALTERNARIA BLACK SPOT (GREY LEAF SPOT)
Alternaria black spot occurs wherever canola is grown in Alberta. Generally the disease is more prevalent in the Peace River region and north central Alberta where moisture and temperature conditions are more favorable for infection and disease development. Significant yield loss may occur when canola is sown on or adjacent to diseased stubble. Periods of warm wet weather favor the pathogens.

Cause
Two fungi, *Alternaria brassicae* and *A. raphani*, are responsible for alternaria black spot.

Symptoms
Infected seed may rot in the ground or produce seedlings with dark spots on the cotyledons or seed leaves. All above-ground plant parts are susceptible to infection. Leaf spots range from grey to black, depending on environmental conditions. Stem and pod lesions first appear as small brown or black dots and may be black or greyish white with dark borders. Infected pods may ripen prematurely and shatter before the crop is mature.

Disease Cycle
The fungi overwinter on infected crop debris, in infected seedlots, and on winter annual weed hosts like stinkweed. Spores are produced in the spring and dispersed by wind to the new crop. During periods of leaf wetness, spores germinate and infect the plants causing leaf spots. New spores are produced on diseased plants and infection cycles continue throughout the summer when environmental conditions are suitable. Seed below sunken pod spots is often infected.

Control
Cultural: Follow a crop rotation with at least three years between cruciferous weeds during a rotation. Incorporate infected stubble into the soil if canola will be sown on adjacent land the following year. Use well-cleaned seed with germination over 90 per cent.

Chemical: None.

Resistant Varieties
None. Argentine type canola is less susceptible to Alternaria black spot than Polish varieties.

FOOT ROT
Foot rot occurs sporadically in canola crops throughout Alberta. Although the disease has not been associated with major yield losses in recent years in Alberta, it is increasing in incidence and severity in other parts of western Canada.

Cause
Several fungi, primarily *Fusarium* spp., *Rhizoctonia solani*, and *Pythium* spp. cause foot rot.

Symptoms and Disease Cycle
During the summer, scattered plants or patches of prematurely ripened plants appear in the crop. Hard, brown, clearly defined lesions occur at the base of the stem and pink spore masses may be apparent during periods of wet weather.

The fungi that cause foot rot are all soil-borne and may persist for years in the soil in the absence of a host. Canker or lesion development may be favored by high soil temperatures or wounds caused by insect feeding. Because foot rot develops quite late in the season, the earlier maturing Polish type canola varieties may escape infection, or lesions may not have time to develop to the point that yield is seriously reduced.

Control
Cultural: Allow at least three years between canola crops and control volunteer canola and cruciferous weeds during the rotation.

Chemical: None

Resistant Cultivars: None.

GREYSTEM AND WHITE LEAF SPOT
Grey stem is prevalent late in the growing season in most canola production areas, however, it usually develops too late to significantly affect crop yields. The disease may occur earlier in crops under stress from lack of moisture, insufficient nitrogen or heavy competition from wild oats.

Cause
A fungus, *Pseudocercosporella capsellae* causes grey stem and white leaf spot.

Symptoms
White leaf spot appears in early summer. As the crop ripens, large, purple to grey speckled stem and pod lesions develop. At harvest time, some plants may be entirely discolored and the field may appear purple or grey.

Disease Cycle
The fungus overwinters on diseased crop stubble and produces spores the following spring. Spores are carried by wind currents into the crop and infection causes white leaf spots to develop. Late in the season, a second period of spore

production occurs and causes rapid disease development on the ripening crop.

Pseudocercosporella capsellae has a wide host range among common cruciferous weeds including ball mustard, shepherd's purse and hare's-ear mustard.

Control
Cultural: Rotation with non-cruciferous crops and control of volunteer canola and cruciferous weeds should reduce the level of infection in the crop.

ASTER YELLOWS

Aster yellows occurs sporadically and is considered a disease of minor importance in Alberta.

Cause
Aster yellows is a mycoplasm-like organism.

Symptoms
A typical symptom of the disease is the formation of small, blue-green, hollow bladders in the place of normal pods. Normal pods may be present on lower portions of the plant.

Disease Cycle
Aster yellows is spread from plant to plant by the six-spotted leafhopper. Disease severity varies with the abundance of the leafhopper vector. Nearly 300 species of plants, including many field crops, are susceptible to this disease.

Control: None.

SWATHING CANOLA

As a high yield canola crop approaches maturity, it may ripen very quickly. Gauging the correct time to swath and combine calls for more care and adjustments than with cereals. Swathing at the optimum stage of ripening reduces green seed problems and seed losses, and ensures the quality required for top grades and prices.

PROPER STAGE TO SWATH CANOLA

To determine when a field of canola is ready to swath, examine plants from different parts of the field. The stage of maturity in an evenly maturing field will vary from plant to plant and area to area within the field. When examining the plants, take into account varying soil types, low lying area, available soil moisture and exposed early ripening areas. Begin to inspect every two to three days when the crop changes from green to yellow-green.

The color of the seed is more important than the overall color of the field in determining the stage of maturity. The best time to swath for optimum seed yield and quality is when all the seeds contain about 30 to 35 per cent moisture. The color of the seeds is a good indicator of seed moisture content. Seeds in all pods on a plant complete filling (physiological maturity) at about 40 per cent moisture and then slowly turn from green to light yellow, or reddish brown to brown, depending on the variety. Once filled, the seeds rapidly lose moisture at about 2 to 3 per cent or more per day, depending on the weather.

Examine only those pods on the main stem. Seeds in pods on the bottom third of the main stem were formed earlier and will turn color much sooner than seeds in the pods on the top third of the plant. When the overall moisture content of the seed from the total plant averages 30 to 35 per cent, about 30 to 40 per cent of the seeds in pods on the main stem only will have changed color or have started to change color. Seeds with only small patches of color should be counted as color changed.

In *B. napus* varieties, most of the seeds that have changed color will be from the bottom third of the stem, while in *B. campestris* varieties, some seed color change will also have occurred in the middle and upper pods. When seeds in the bottom pods turn color, seeds in the top, last-formed pods are filled or nearly filled.

Most of the seeds will be firm, and roll, as opposed to break, when pressed between the forefinger and thumb.

Swathing earlier at a higher moisture content will result in lower yields, immature shriveled seeds, and green seed problems, especially if very hot and dry, windy weather occurs shortly after swathing. On the other hand, swathing later when seed moisture content is much lower, around 20 per cent, results in fluffy windrows susceptible to blowing, increased shattering and frost damage. To reduce shattering losses, over-ripe fields should be swathed when humidity is high, such as after a rain, after a heavy dew or at night.

SWATHING LODGED AND UNEVEN CANOLA

In lodged crops, the seed on the upper side of the stem will mature ahead of that shaded from the sunlight but in the same section of the stem. Under these conditions, swath when about 40 to 50 per cent of the seed in the exposed pods has turned color.

It is difficult to determine when to swath unevenly maturing fields. Uneven maturity is usually the result of uneven spring germination where two or more flushes of germination have occurred. Determine which of the different stages of maturing plants are the majority. Seeds with a high moisture content (over 45%) from swathed, immature plants in an uneven maturing field will ripen in the windrow unless they are frozen or dried up by very warm weather. If the weather is warm, the immature seeds may shrivel and pass easily through the combine or will have green color. In this situation, swath when most of the seeds have a low moisture content so that the immature plants have a chance to mature further. **From the producers' surveys:**

- **60 per cent of the top group reported medium to heavy lodging compared to only 30 per cent of the low group.**
- **42 per cent of the top group swathed when the average seed moisture content was at 30 per cent or more,**

compared to 25 per cent of the low group. The majority of the survey swathed at 15 to 25 per cent seed moisture content. Considering that a canola crop dries at a rate of about 2 per cent moisture a day under normal dry weather, this means they could have swathed 5 to 7 days earlier. This saves on shatter losses, as well as cuts down frost risk damage to the crop.

COMBINING AND STORAGE

Canola in the windrow is ready to pick up and thresh when the seed temperature and moisture content have dropped to a safe storage level and most seeds are mature with no green color. If there are some green seeds, a few more days in the windrow is probably all that is needed. Green seeds may ripen in the windrow but they do not cure significantly once they are combined. Before combining, use a crush strip to make sure the seeds are not green inside. A small per centage of seeds with green meat will reduce the grade.

If wide swathers are used on tall, heavy crops, the result is very large windrows which take a longer time to cure, especially at the centre of the windrow. Bunching in the windrows also may contribute to a green seed problem as the crop dries out and cures unevenly. Canola is considered dry for marketing at 10 per cent moisture content. However, 8 to 9 per cent moisture at temperatures below 20°C are necessary for long-term storage. The relationship of canola seed moisture content and temperature, to safe storage, is shown in Figure 18.

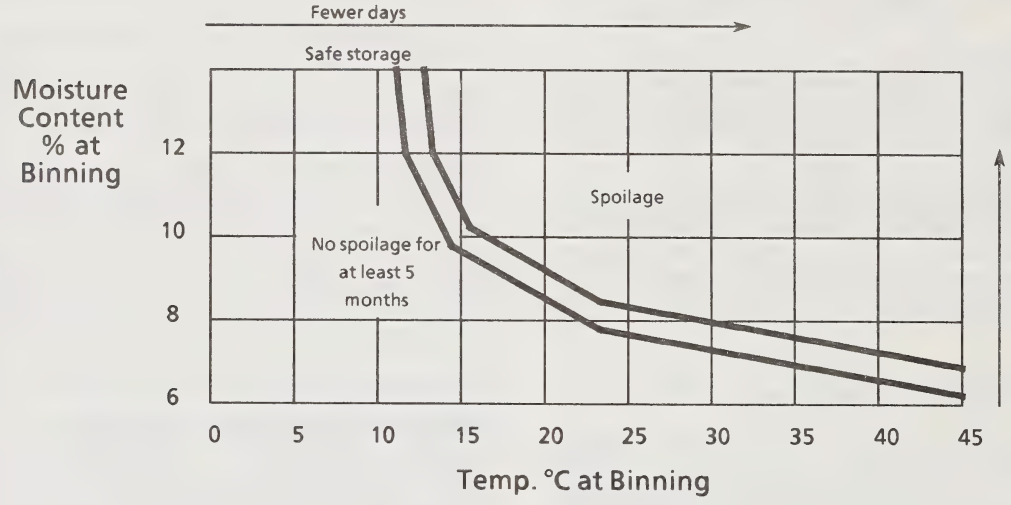


Figure 18. Canola Storage Time Chart.

Any combination of canola seed temperature and moisture content to the left of the line on the chart is acceptable for storage from fall to spring. Only conditions of less than 9 per cent moisture and cooler than 15°C require only occasional monitoring. The chart does not allow for deterioration due to infestations by insects and mites which can occur in hot dry seed.

High moisture content but low temperature, or high seed temperature even though the seed is very dry, serve as warnings that extra attention is needed. There could be errors in the measurement of either grain temperature or moisture content. Also, moisture content from different parts of the field being harvested may vary. These measurement errors may or may not indicate the canola is in an unsafe storage condition.

If canola seed temperature is kept below 20°C, heat damage cannot occur. Regardless of seed moisture, harvesting temperature or damaged seed, maintain a temperature below 20°C.

The temperature of harvested canola is frequently in the range of 25 to 35°C on a warm, sunny afternoon. In addition, freshly harvested seed can maintain a high respiration rate for up to six weeks before becoming dormant. This is a condition often referred to as "sweating." It is a very unstable condition in a bin of canola.

Monitoring of the seed condition is very important so that you can respond to the danger of imminent spoilage before major damage occurs. Seed that has reached a point where it could deteriorate can be conditioned by aeration, natural air drying or heated air drying, so that it can be safely stored for longer periods of time. Many publications on conditioning canola are

available at your district agriculturist's office.

From the producers' survey:

- **45 per cent of the top group combined when seed moisture content was 8 per cent or less, compared to 25 per cent of the low group. The majority of the growers combined at between 8 to 10 per cent seed moisture.**
- **5 per cent of the top group reported some heating damage, compared to 10 per cent of the low group.**
- **The average dockage of the top group was 3.7 per cent, compared to 9.4 per cent of the low group.**
- **About 15 per cent of the survey reported having green seed problems over 2 per cent.**

To consistently achieve high yields and grades, pay careful attention to selection of the proper variety for the location; rapid and uniform stand establishment; weed, insect, and disease control; proper rotation; timely swathing; harvesting at the right moisture and temperature; and adequate storage and conditioning.

SUMMARY

Average yields of canola in Alberta have increased somewhat in the past 20 years through new varieties and improvements in farm machinery, new herbicides, insecticides and fungicides, increased fertilizer use and better cultural practices learned from research and experience. However, average yields of 19 to 22 bushels per acre are still well below the potential in the province. There is an opportunity for increased yields through the full implementation of currently known technology into a well planned crop production system. Yield advances from new higher yielding varieties more adapted to regional conditions should become available in the near future. However, if the best production techniques now used by top growers were adopted by all growers, this would probably have the greatest impact on raising the provincial yield average and prosperity of our growers. Before growers can utilize these methods, they have to become aware of them. That has been the purpose of this Canola Production in Alberta manual.

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